Sacramento Area Hydrology Model (SAHM)

Guidance Document

Clear Creek Solutions, Inc.
www.clearcreeksolutions.com

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and the electronic version of this document,
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FOREWORD

The Sacramento Area Hydrology Model (SAHM) is a tool for analyzing the hydromodification effects of land development projects and sizing solutions to mitigate the increased runoff from these projects. This section of the guidance documentation provides background information on the definition and effects of hydromodification and relevant findings from technical analyses conducted in response to regulatory requirements. It also summarizes the current Hydromodification Management Standard and general design approach for hydromodification control facilities, which led to the development of the SAHM.

Effects of Hydromodification

Urbanization of a watershed modifies natural watershed and stream processes by altering the terrain, modifying the vegetation and soil characteristics, introducing pavement and buildings, installing drainage and flood control infrastructure, and altering the condition of stream channels through straightening, deepening, and armoring. These changes affect hydrologic characteristics in the watershed (rainfall interception, infiltration, runoff and stream flows), and affect the supply and transport of sediment in the stream system. The change in runoff characteristics from a watershed caused by changes in land use conditions is called *hydrograph modification*, or simply hydromodification.

As the total area of impervious surfaces increases in previously undeveloped areas, infiltration of rainfall decreases, causing more water to run off the surface as overland flow at a faster rate. Storms that previously didn't produce runoff under rural conditions can produce erosive flows. The increase in the volume of runoff and the length of time that erosive flows occur ultimately intensify sediment transport, causing changes in sediment transport characteristics and the hydraulic geometry (width, depth, slope) of channels. The larger runoff durations and volumes and the intensified erosion of streams can impair the beneficial uses of the stream channels.

Regulatory Context

The California Regional Water Quality Control Board (Water Board) requires stormwater programs to address the increases in runoff rate and volume from new and redevelopment projects where those increases could cause increased erosion of receiving streams. Phase 1 municipal stormwater permits in Sacramento County contain requirements to develop and implement hydromodification management plans (HMPs) and to implement associated management measures.

Development of the Sacramento Area Hydrology Model

The concept of designing a flow duration control facility is relatively new and, as described above, requires the use of a continuous simulation hydrologic model. To facilitate this design approach, Clear Creek Solutions (CCS) has created a user-friendly, automated modeling and flow duration control facility sizing software tool adapted from its Western Washington Hydrology Model (WWHM). The WWHM was developed in

2001 for the Washington State Department of Ecology to support Ecology's *Stormwater Management Manual for Western Washington*[1] and assist project proponents in complying with the Western Washington hydromodification control requirements. The Sacramento Area Hydrology Model (SAHM) is adapted from WWHM Version 4, but has been modified to represent Sacramento County hydrology and enhanced to be able to size other types of control measures and low impact development (LID) techniques for flow reduction as well.

SAHM is a useful tool in the design process, but must be used in conjunction with local design guidance to ensure compliance for specific projects. The reader should refer to Appendix C and local stormwater program guidance for additional information and suggestions for using the SAHM.

Acknowledgements

The following individuals are acknowledged for their contributions to the development of SAHM and guidance documentation:

- Doug Beyerlein, Joe Brascher, and Gary Maxfield, of Clear Creek Solutions, Inc., for development of WWHM, BAHM, and SAHM and preparation of the SAHM guidance documentation.
- Scott Taylor and Remi Candaele of RBF Consulting for providing SAHM meteorological data, maps, and technical specifications.

[1] Washington State Department of Ecology. 2001. Stormwater Management Manual for Western Washington. Volume III: Hydrologic Analysis and Flow Control Design/BMPs. Publication No. 99-13. Olympia, WA.

TABLE OF CONTENTS

INTRODUCTION TO SAHM

SAHM is the Sacramento Area Hydrology Model. SAHM is based on the WWHM (Western Washington Hydrology Model) stormwater modeling platform. WWHM was originally developed for the Washington State Department of Ecology. More information about WWHM can be found at www.clearcreeksolutions.com. More information can be found about the Washington State Department of Ecology's stormwater management program and manual at www.ecy.wa.gov/programs/wq/stormwater/manual.html.

Clear Creek Solutions is responsible for SAHM and the SAHM guidance documentation.

This guidance documentation is organized so as to provide the user an example of a standard application using SAHM (described in *Quick Start*) followed by descriptions of the different components and options available in SAHM. The *Tips and Tricks* section presents some ideas of how to incorporate LID (Low Impact Development) facilities and practices into the SAHM analysis. Appendices A and B provide a full list of the HSPF parameter values used in SAHM. Appendix C contains additional guidance and recommendations by the stormwater programs that have sponsored the SAHM development. Appendix D is a checklist for use by SAHM project reviewers. Appendix E documents the bioretention modeling methodology used in SAHM. Appendix F demonstrates how to set up a complex project with multiple stormwater mitigation facilities and multiple points of compliance.

Throughout the guidance documentation notes using this font (sans-serif italic) alert the user to actions or design decisions for which guidance must be consulted that is external to the SAHM software, either provided in Appendix C of this guidance documentation or by the local municipal permitting agency.

Purpose

The purpose of SAHM is to size hydromodification management or flow control facilities to mitigate the effects of increased runoff (peak discharge, duration, and volume) from proposed land use changes that impact natural streams, wetlands, and other water courses.

SAHM provides:

- A uniform methodology for Sacramento County
- A more accurate methodology than single-event design storms
- An easy-to-use software package

SAHM is based on:

- Continuous simulation hydrology (HSPF)
- Actual long-term recorded precipitation data
- Measured pan evaporation data
- Existing vegetation (for pre-project conditions)

- Regional HSPF parameters

Computer Requirements

- Windows 2000/XP/Vista/7/8 with 300 MB uncompressed hard drive space
- Internet access (only required for downloading SAHM, not required for executing SAHM)
- Pentium 3 or faster processor (desirable)
- Color monitor (desirable)

Before Starting the Program

- Knowledge of the site location and/or street address.
- Knowledge of the actual distribution of existing site soil by category (A, B, C, or D).
- Knowledge of the actual distribution of existing and proposed site land cover by category (grass, agricultural land, urban, or trees).
- Knowledge of the actual distribution of existing and proposed site topography by category (flat, moderate, steep, or very steep slope).
- Knowledge of the planned distribution of the proposed development (buildings, streets, sidewalks, parking, lawn areas) overlying the soil categories.

SAHM OVERVIEW

The SAHM software architecture and methodology is the same as that developed for BAHM (Bay Area Hydrology Model), SDHM (San Diego Hydrology Model), SOHM (South Orange Hydrology Model), and WWHM and uses HSPF as its computational engine[2]. Like BAHM, SDHM, SOHM, and WWHM, SAHM is a tool that generates flow duration curves for the pre- and post-project condition and then sizes a flow duration control pond/basin or vault and outlet structure to match the pre-project curve. The software package consists of a user-friendly graphical interface with screens for input of pre-project and post-project conditions; an engine that automatically loads appropriate parameters and meteorological data and runs continuous simulations of site runoff to generate flow duration curves; a module for sizing or checking the control measure to achieve the hydromodification control standard; and a reporting module.

The HSPF hydrology parameter values used in SAHM are based on best professional judgment using our experience with calibrated watersheds in other parts of California. SAHM uses the Sacramento County long-term hourly precipitation data records selected to represent Sacramento County rainfall patterns.

HSPF is the U.S. Geological Survey and U.S. Environmental Protection Agency continuous simulation hydrology software package maintained by AQUA TERRA Consultants. The HSPF continuous simulation hydrology model is preferred over single-event hydrology models because of its ability to compute and keep track of all of the individual components of the hydrologic cycle including surface runoff, interflow, groundwater, soil moisture, and evapotranspiration. HSPF, since its introduction in 1980, has become the industry standard for hydrologic modeling.

One of the major advantages of continuous simulation hydrologic modeling is the ability to accurately determine soil moisture conditions immediately prior to storm events. Single-event hydrologic models have to make assumptions about the antecedent soil moisture conditions – assumptions which are often not accurate or appropriate. This is an important distinction because antecedent soil moisture conditions play a major role in determining the amount and timing of runoff.

Not all continuous simulation hydrologic models handle the calculation of soil moisture conditions in the same level of detail. HSPF uses a potential evapotranspiration time series to compute actual evapotranspiration each time step. HSPF uses parameter values to determine the proportion of the actual evapotranspiration from interception storage, upper soil layer storage, lower soil zone layer storage, groundwater storage, and base flow. Other continuous simulation hydrologic models, SWMM included, use a much more simplified approach to determining soil moisture. Such simplified approaches do not accurately reflect the seasonal and daily variability of the actual evapotranspiration and its effects on soil moisture.

[2] SAHM is based on WWHM Version 4.

SAHM computes stormwater runoff for a site selected by the user. SAHM runs HSPF in the background to generate a hourly runoff time series from the available rain gage data over a number of years. Stormwater runoff is computed for both pre-project and post-project land use conditions. Then, another part of the SAHM routes the post-project stormwater runoff through a stormwater control facility of the user's choice.

SAHM uses the pre-project peak flood values from an annual series of individual peak events to compute the pre-project 2-year through 25-year flood frequency values[3]. The post-project runoff 2-year through 25-year flood frequency values are computed at the outlet of the proposed stormwater facility. The model routes the post-project runoff through the stormwater facility. As with the pre-project peak flow values, partial duration post-project flow values are selected by the model to compute the developed 2-year through 25-year flood frequency.

The pre-project 2-year peak flow is multiplied by a percentage (10 percent) to set the lower limit of the erosive flows, in accordance with the current HMP performance criteria. The pre-project 10-year peak flow is the upper limit. A comparison of the pre-project and post-project flow duration curves is conducted for 100 flow levels between the lower limit and the upper limit. The model counts the number of hourly intervals that pre-project flows exceed each of the flow levels during the entire simulation period. The model does the same analysis for the post-project mitigated flows.

Low impact development (LID)/best management practices (BMPs) have been recognized as opportunities to reduce and/or eliminate stormwater runoff at the source before it becomes a problem. They include compost-amended soils, bioretention, permeable pavement, green roofs, rain gardens, and vegetated swales. All of these approaches reduce stormwater runoff. SAHM can be used to determine the magnitude of the reduction from each of these practices and the amount of stormwater detention storage still required to meet HMP requirements.

Note: The Sacramento Stormwater Quality Partnership *Stormwater Quality Design Manual* and the City and County of Sacramento *Drainage Manual – Volume II Hydrology* should be consulted to make sure that SAHM solutions are consistent with city and county design specifications.

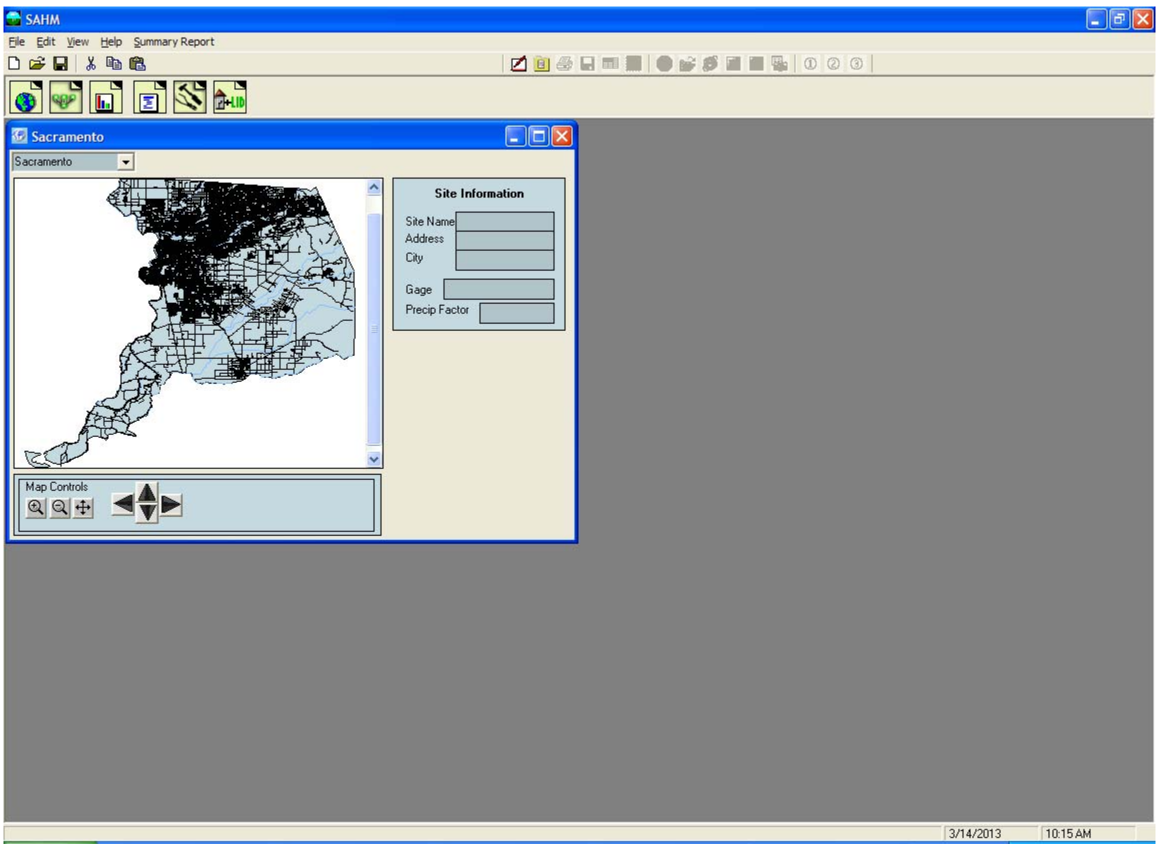
[3] The actual flood frequency calculations are made using the Weibull flood frequency equation.

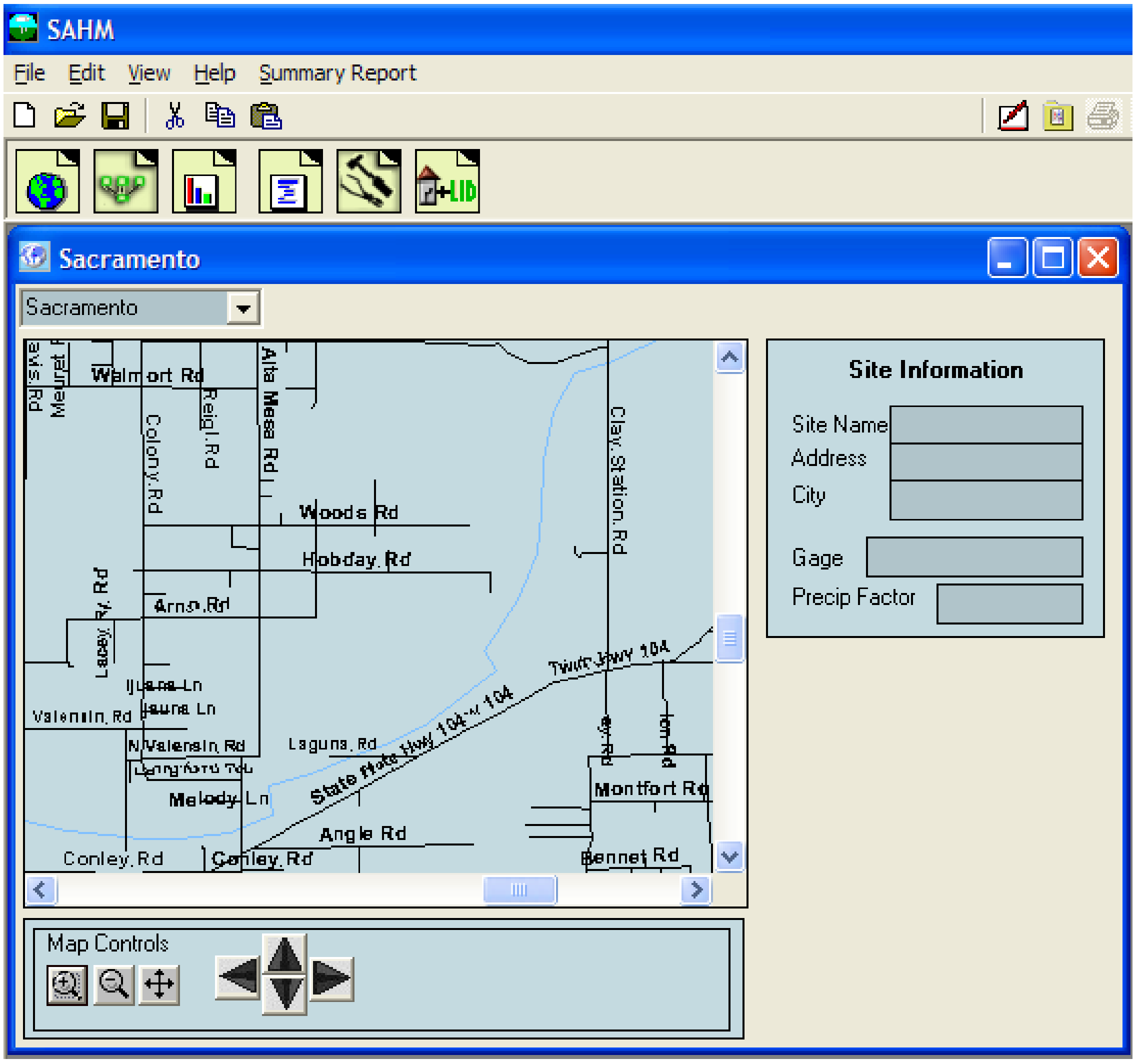
QUICK START

Quick Start very briefly describes the steps to quickly size a stormwater detention pond using SAHM. New users should read the descriptions of the SAHM screens, elements, and analysis tools before going through the steps described below.

1. Open SAHM.

SAHM will open with a map of Sacramento County.



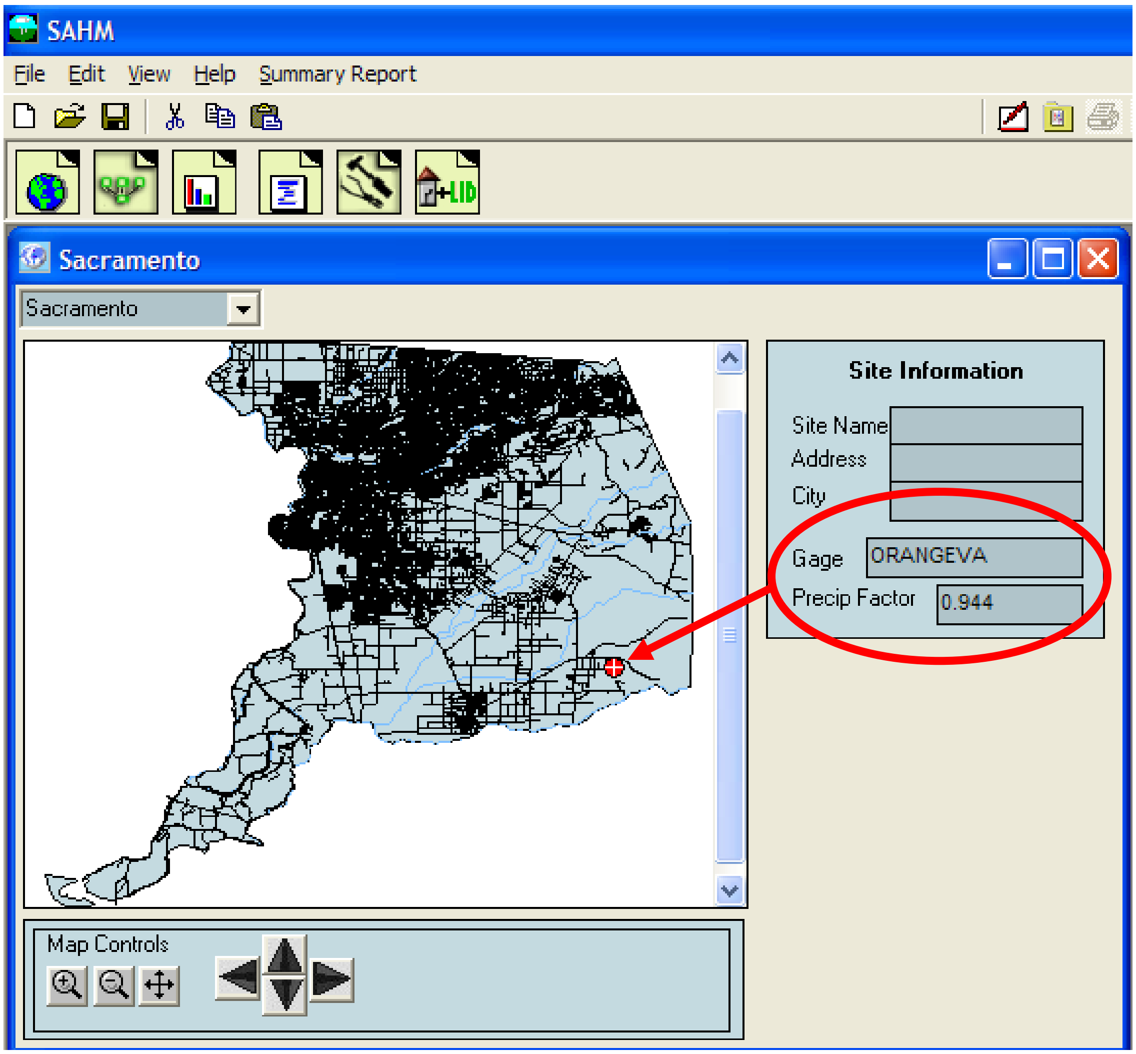


The map controls can be used to enlarge a specific area on the street map layer. This option helps to locate the specific project site.

When the street map layer is enlarged a sufficient amount the individual street names are shown on the map.

2. Select the project site location.

Locate the project site on the map. Use the map controls to magnify a portion of the map, if needed. Select the project site by left clicking on the map location. A red square will be placed on the map identifying the project site.



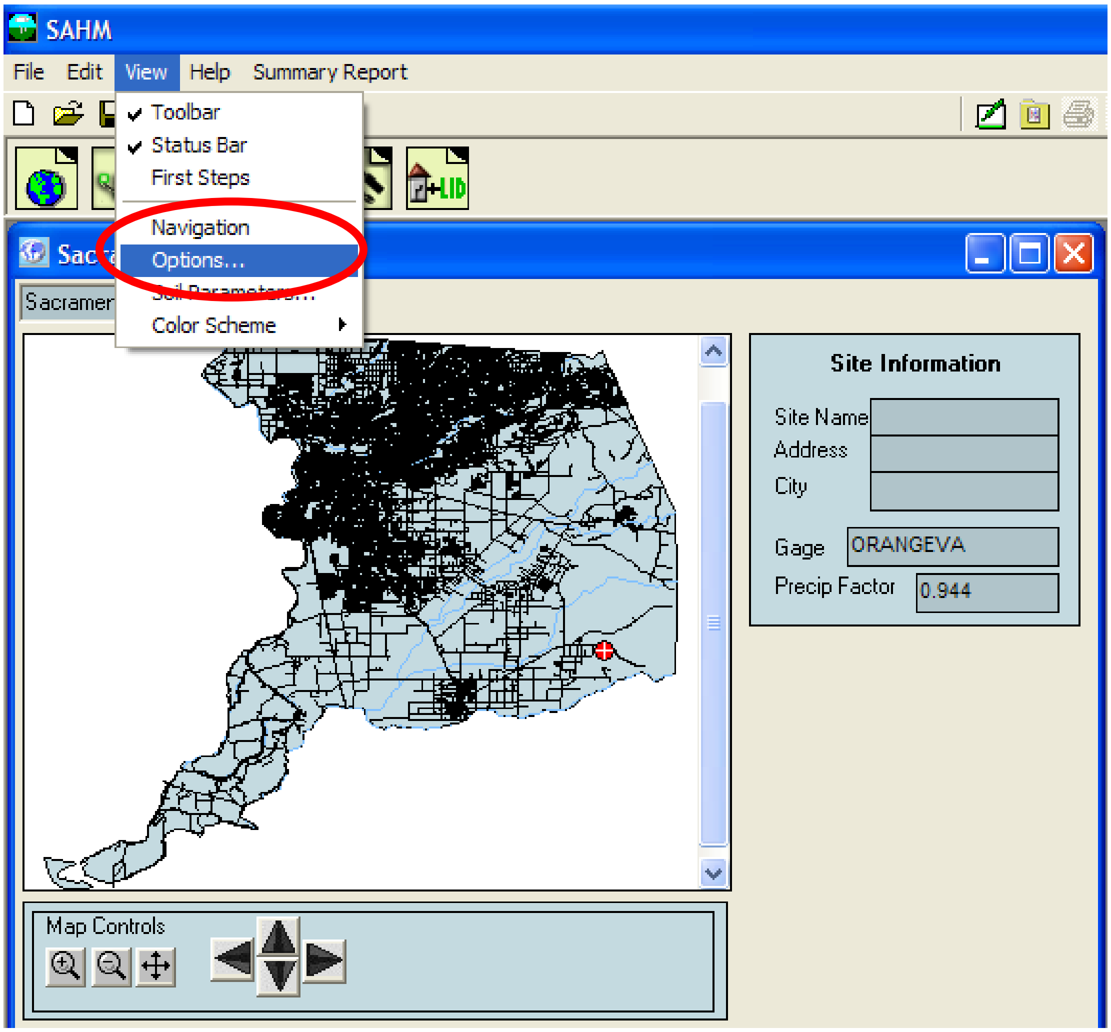
SAHM selects the appropriate rain gage record and precipitation multiplication factor for the project site from the available long-term hourly precipitation records provided by Sacramento County. Sacramento County has four long-term hourly precipitation records: Elk Grove, Natomas, Orangevale, and Rancho Cordova.

For this example we will use the Orangevale rain gage with a precipitation factor of 0.944. The value of 0.944 is based on county isohyetal information provided by Sacramento County GIS. The hourly precipitation data will be multiplied by this value to represent the actual precipitation at the project site.

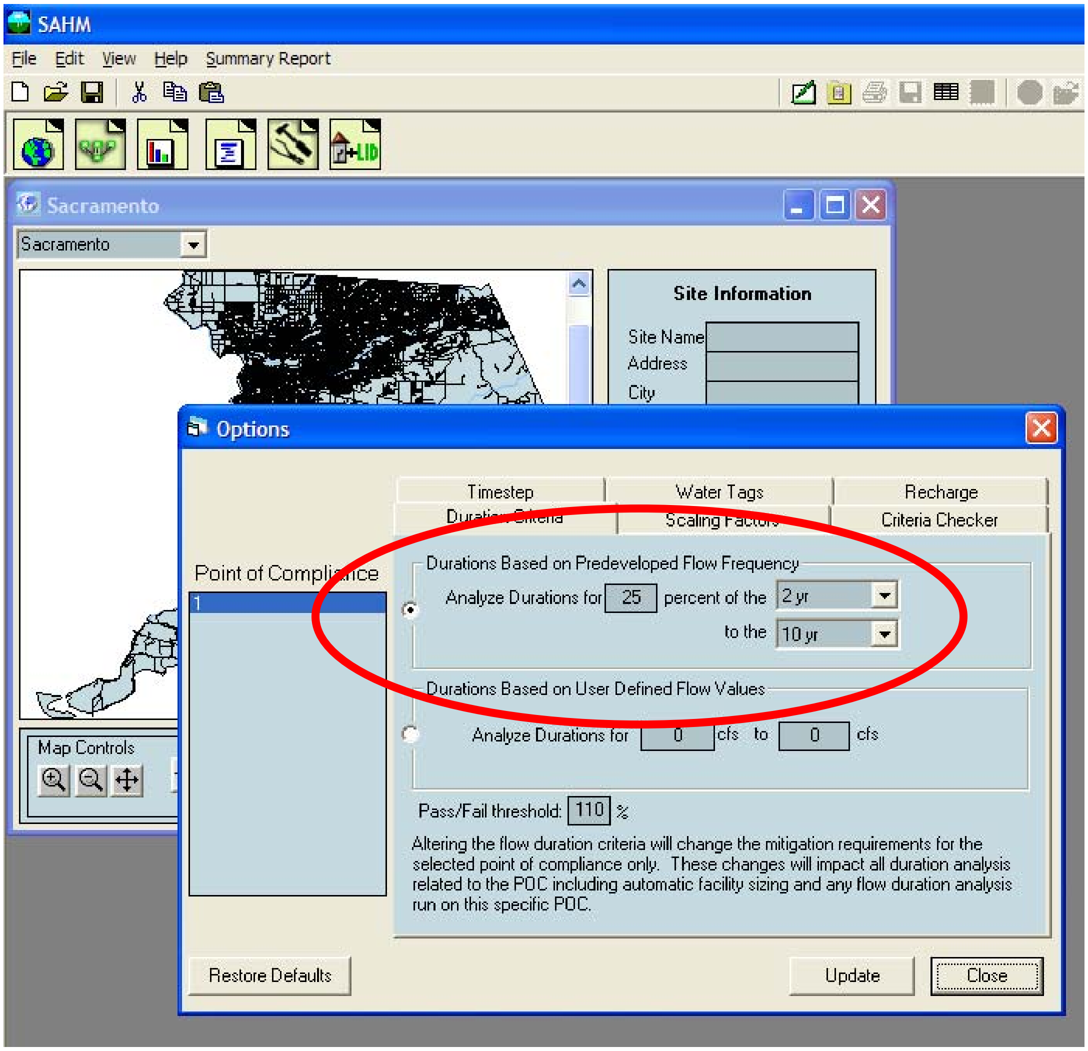
The site name, address, and city information are optional. This information is not used by SAHM, but will be included in the project report summary.

3. Select the lower threshold value for the flow duration analysis.

The default lower threshold value for the flow duration analysis is 25% of the 2-year flow.

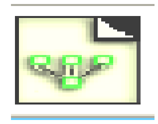


To view the flow duration lower and upper threshold values select View, Options.



If appropriate, the default SAHM flow duration lower threshold of 25% of the 2-year flow and the upper threshold of 100% of the 10-year value can be changed.

4. Use the tool bar (immediately above the map) to move to the Scenario Editor. Click on the General Project Information button.



The General Project Information button will bring up the Schematic Editor.

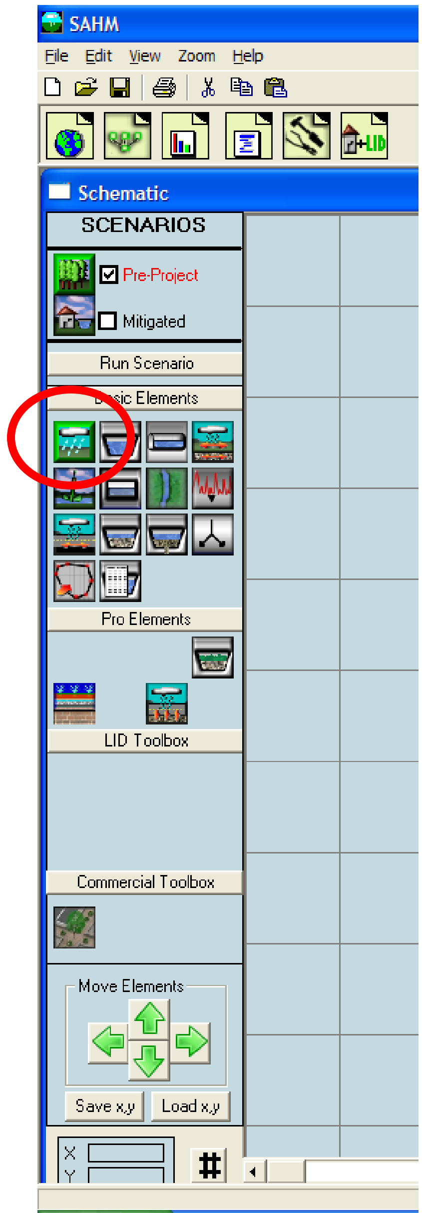
The schematic editor screen contains two scenarios: Pre-Project and Mitigated.

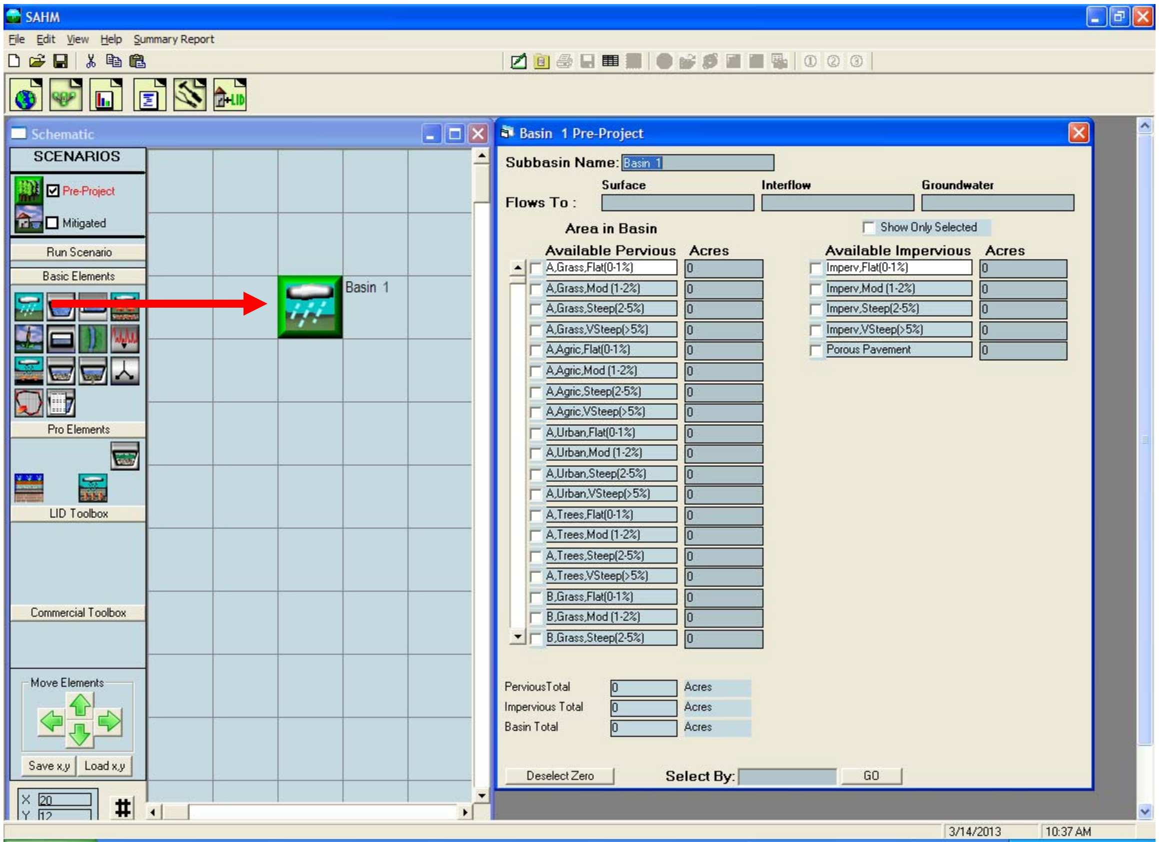
Set up first the Pre-project scenario and then the Mitigated scenario.

Check the Pre-project scenario box.

Left click on the Basin element under the Elements heading. The Basin element represents the project drainage area. It is the upper left element.

Select any grid cell (preferably near the top of the grid) and left click on that grid. The land use basin will appear in that grid cell.





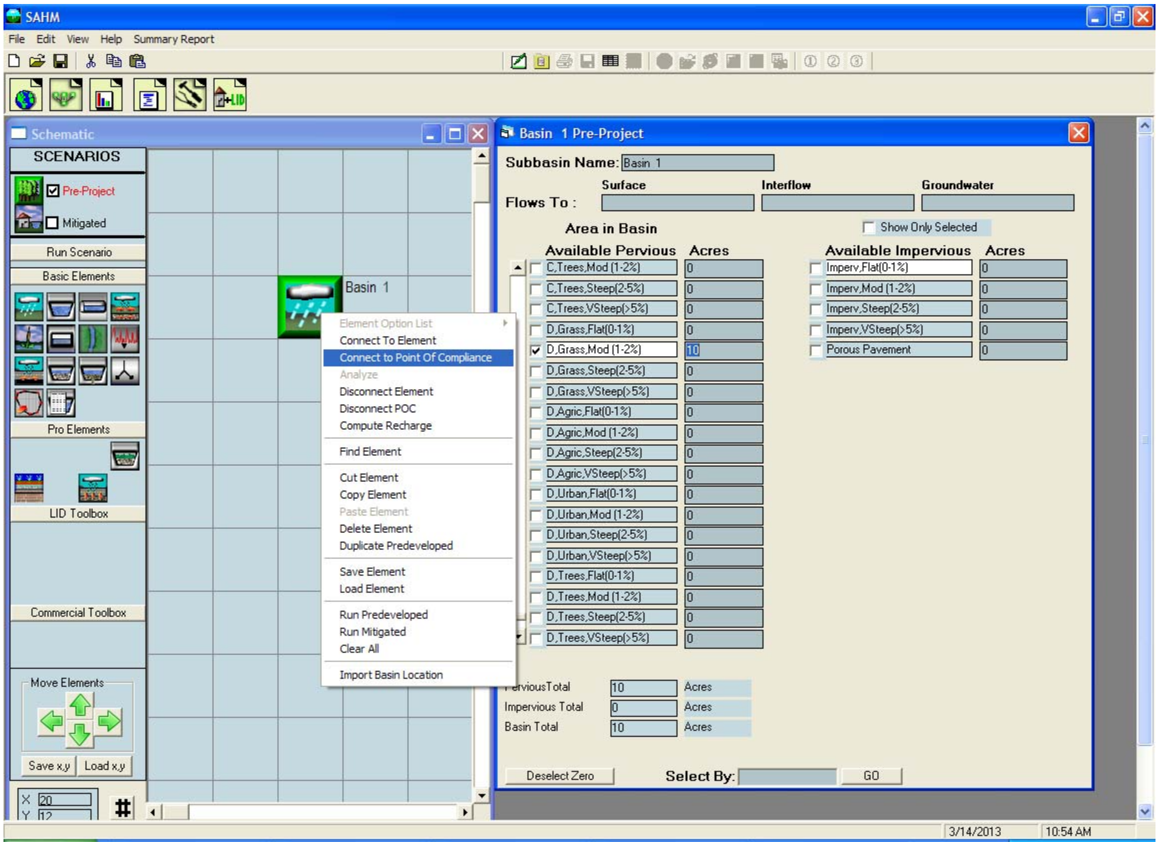
To the right of the grid is the land use information associated with the landuse basin element. Select the appropriate soil, land cover, and land slope for the Pre-project scenario. Soils are based on SCS general categories A, B, C, and D.

Land cover is based on the native vegetation for the Pre-project area and the planned vegetation for the planned development (Mitigated scenario). The SAHM land cover categories are grass, agricultural land, urban vegetation (lawns, flowers, and planted shrubs), and trees.

Land slope is divided into flat (0-1%), moderate (1-2%), steep (2-5%), and very steep (>5%).

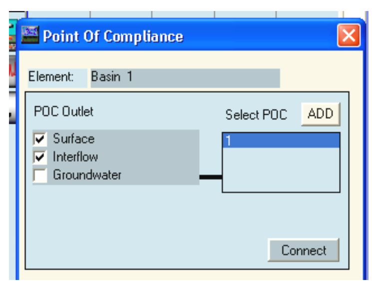
HSPF parameter values in SAHM have been adjusted for the different soil, land cover, and land slope categories based on the professional judgment and experience of Clear Creek Solutions HSPF modelers in northern California.

For this example we will assume that the Pre-project land use is 10 acres of D soil with grass vegetation on a moderate slope (1-2%).

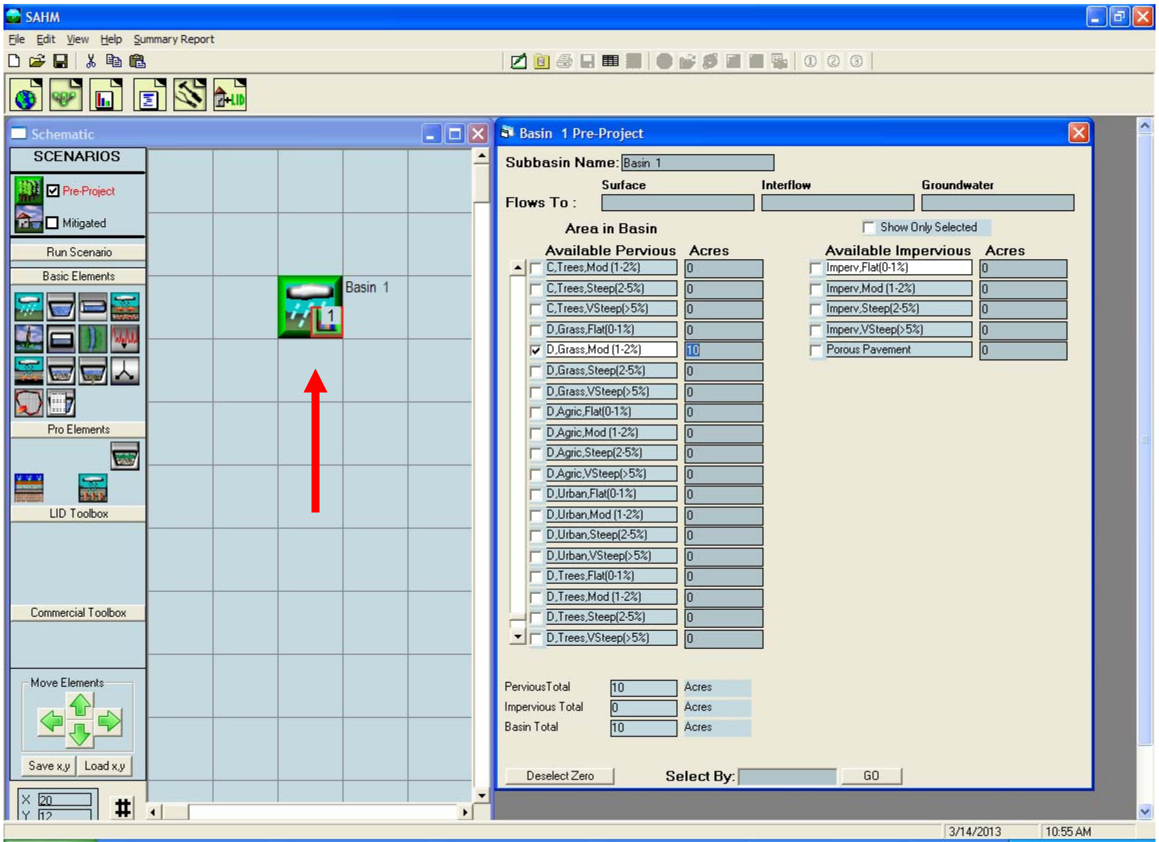


The exit from this land use basin will be selected as our point of compliance for the Pre-project scenario. Right click on the basin element and highlight Connect to Point of Compliance (the point of compliance is defined as the project location at which the runoff from both the Pre-project scenario and the Mitigated scenario are compared).

The Point of Compliance screen will be shown for Pre-project Basin 1. The POC (Point of Compliance) outlet has been checked for both surface runoff and interflow (shallow subsurface flow). These are the two flow components of stormwater runoff. Do not check the groundwater box unless there is observed and documented base flow on the project site.

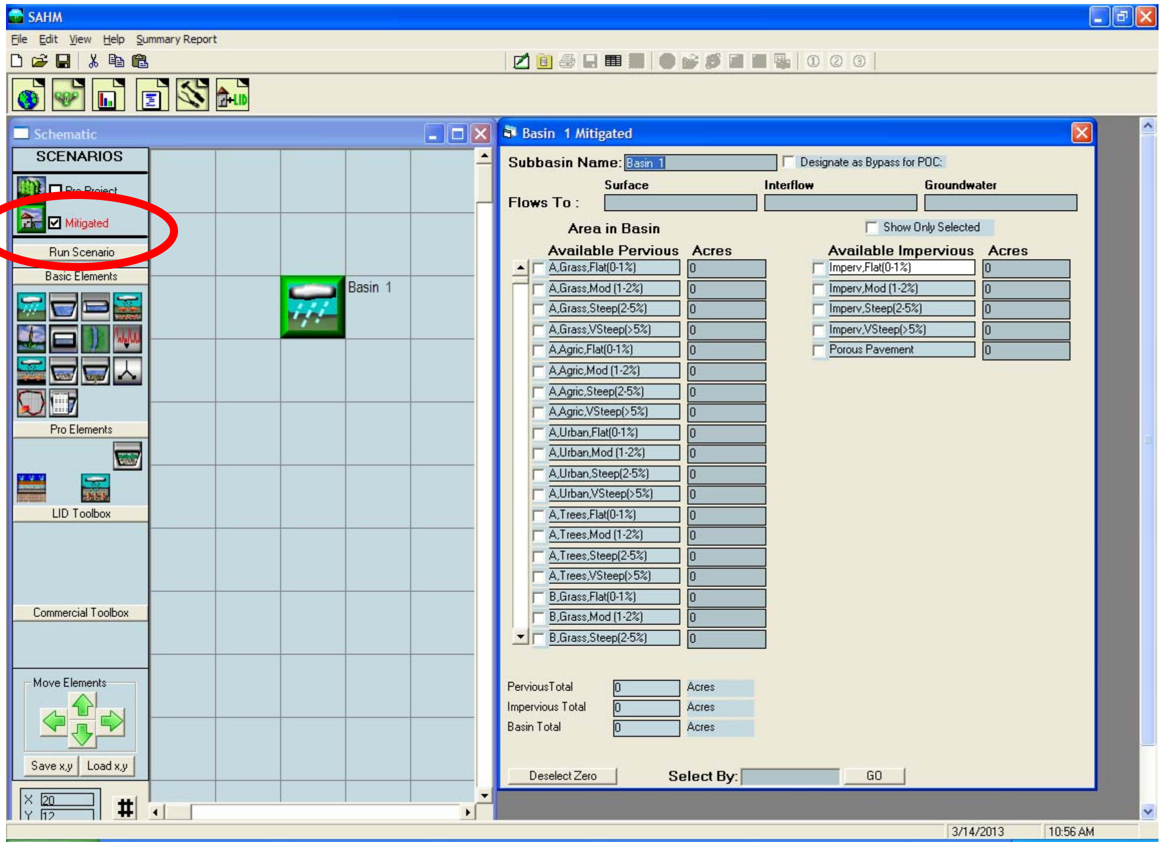


Click the Connect button in the low right corner to connect this point of compliance to the Pre-project basin.

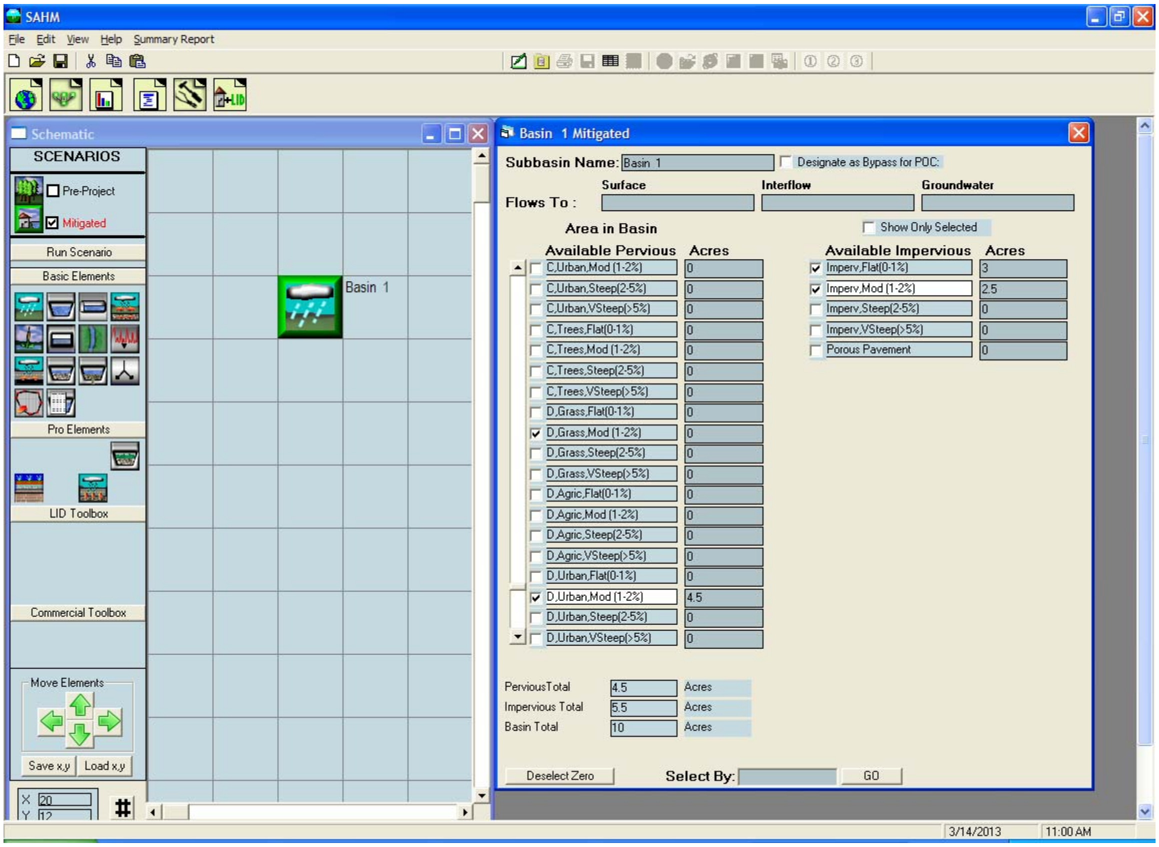


After the point of compliance has been added to the land use basin the basin element will change. A small box with a bar chart graphic and a number will be shown in the lower right corner of the basin element. This small POC box identifies this basin as a point of compliance. The number is the POC number (e.g., POC 1).

5. Set up the Mitigated scenario.



First, check the Mitigated scenario box and place a land use basin element on the grid.

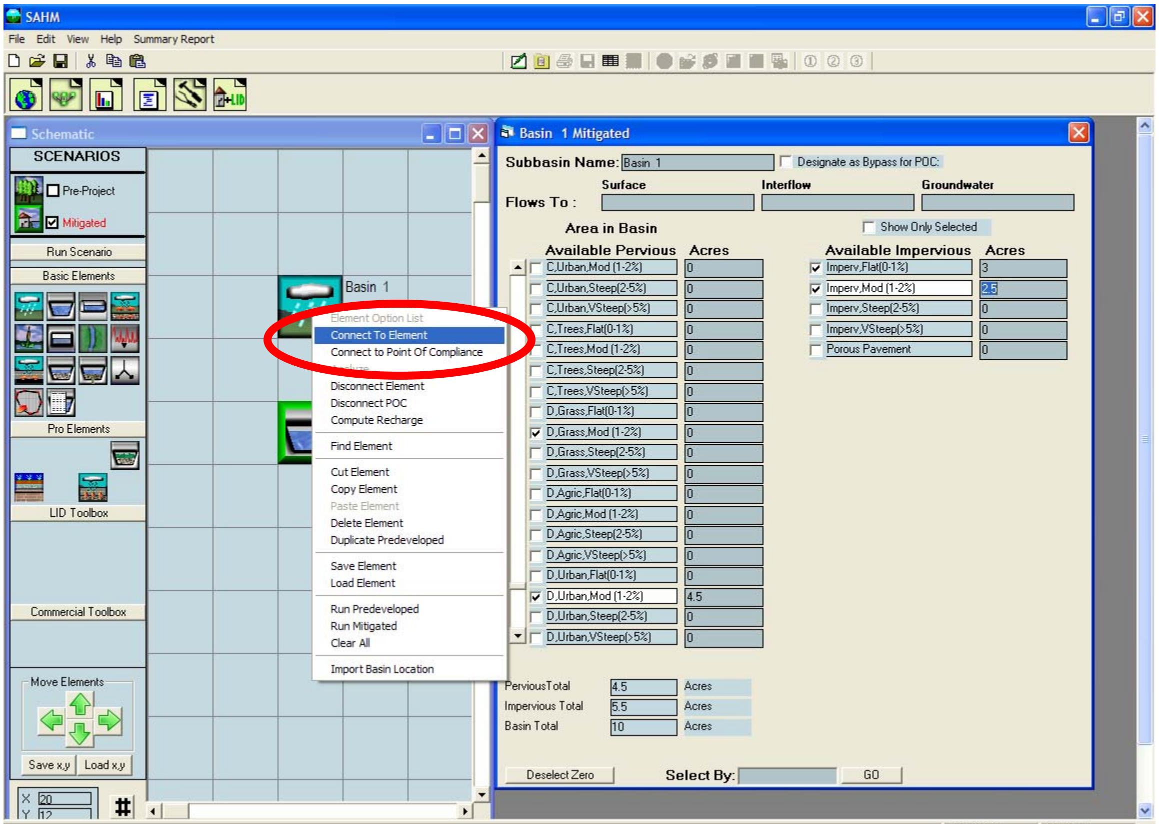


For the Mitigated land use we have:

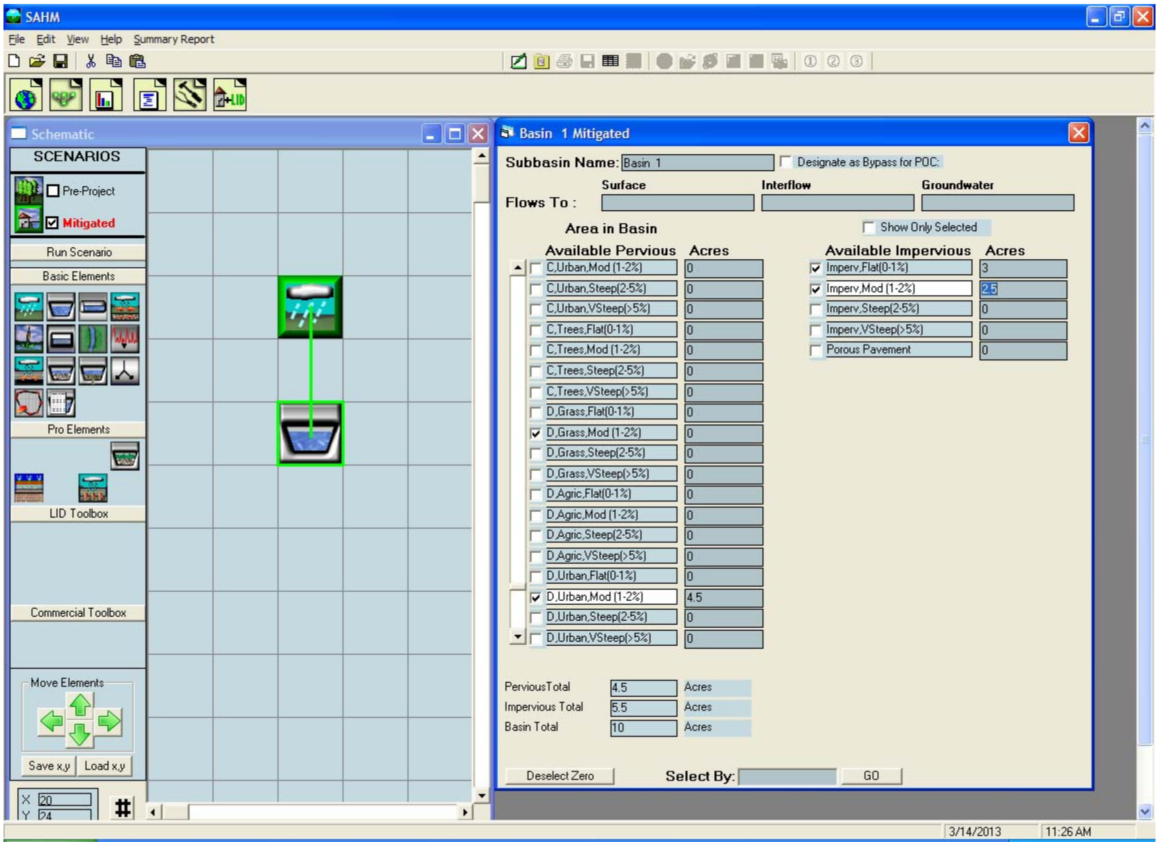
4.5 acres of D soil, urban vegetation, moderate slope
3 acres of impervious, flat slope
2.5 acres of impervious, moderate slope

We will add a trapezoidal pond downstream of the basin.

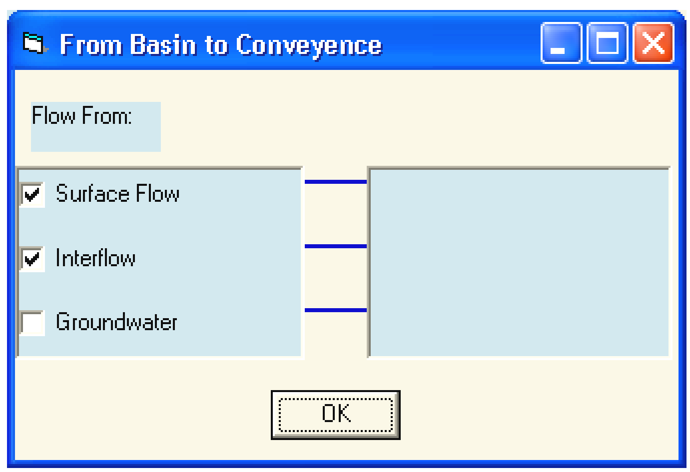
The impervious land categories include roads, roofs, sidewalks, parking, and driveways. All are modeled the same, except that steeper slopes have less surface water retention storage prior to the start of surface runoff.

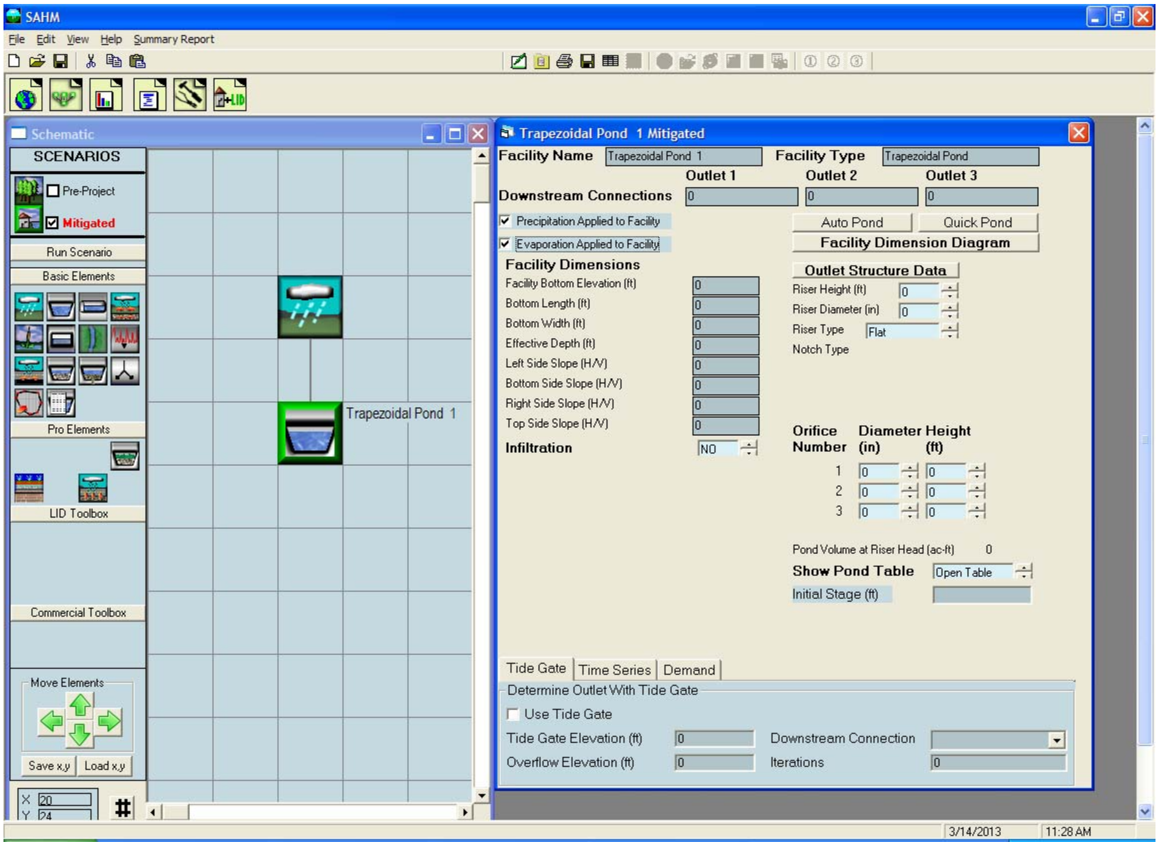


The trapezoidal pond element is placed below the basin element on the grid. Right click on the basin and select Connect To Element. A green line will appear with one end connected to the basin.

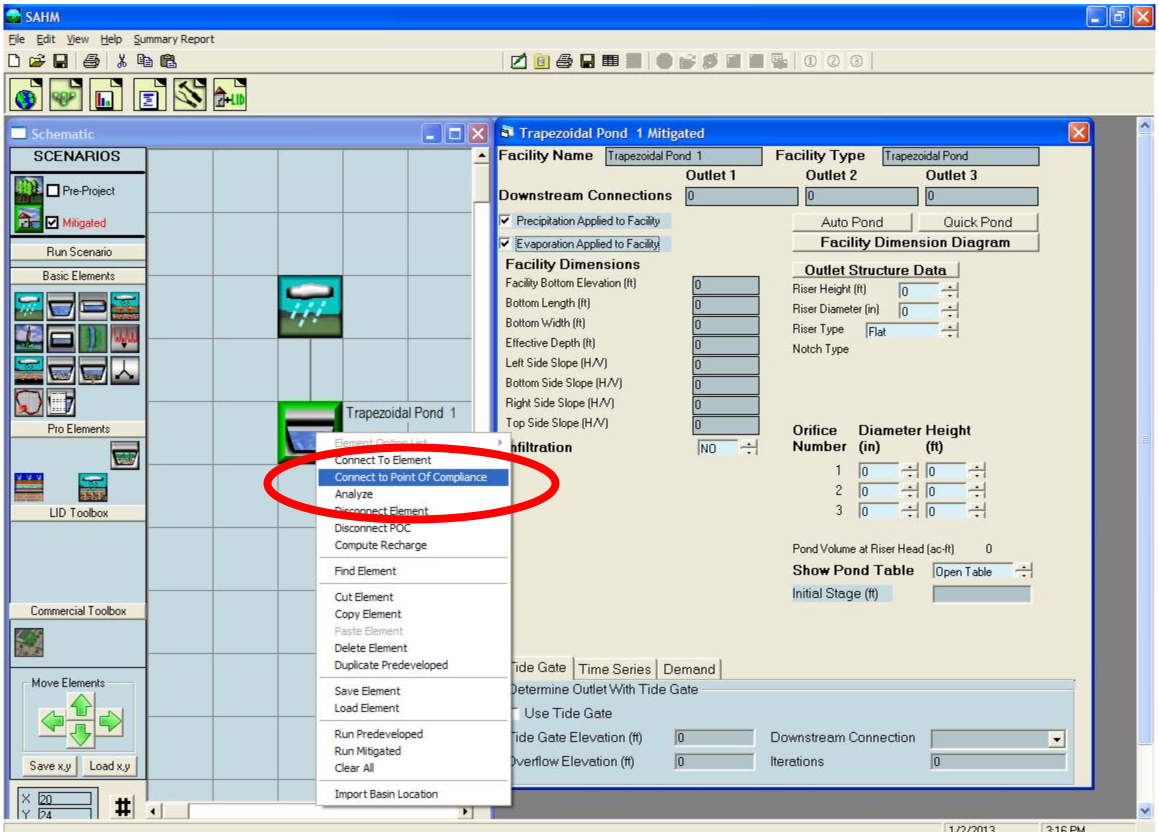


With the mouse pointer pull the other end of the line down to the trapezoidal pond and click on the pond. This will bring up the From Basin to Conveyance screen. As with the Pre-project scenario we want to only connect the surface flow and the interflow (shallow subsurface runoff) from the basin to the pond. Click OK.

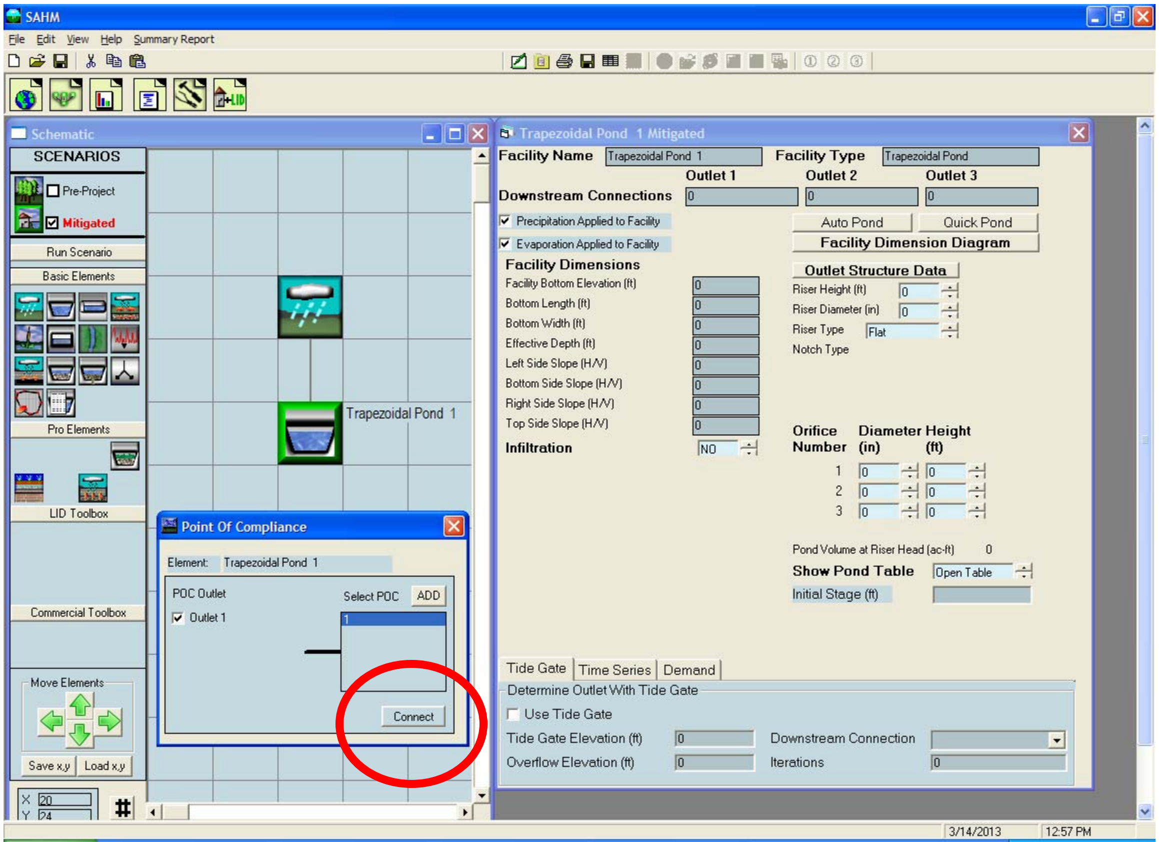




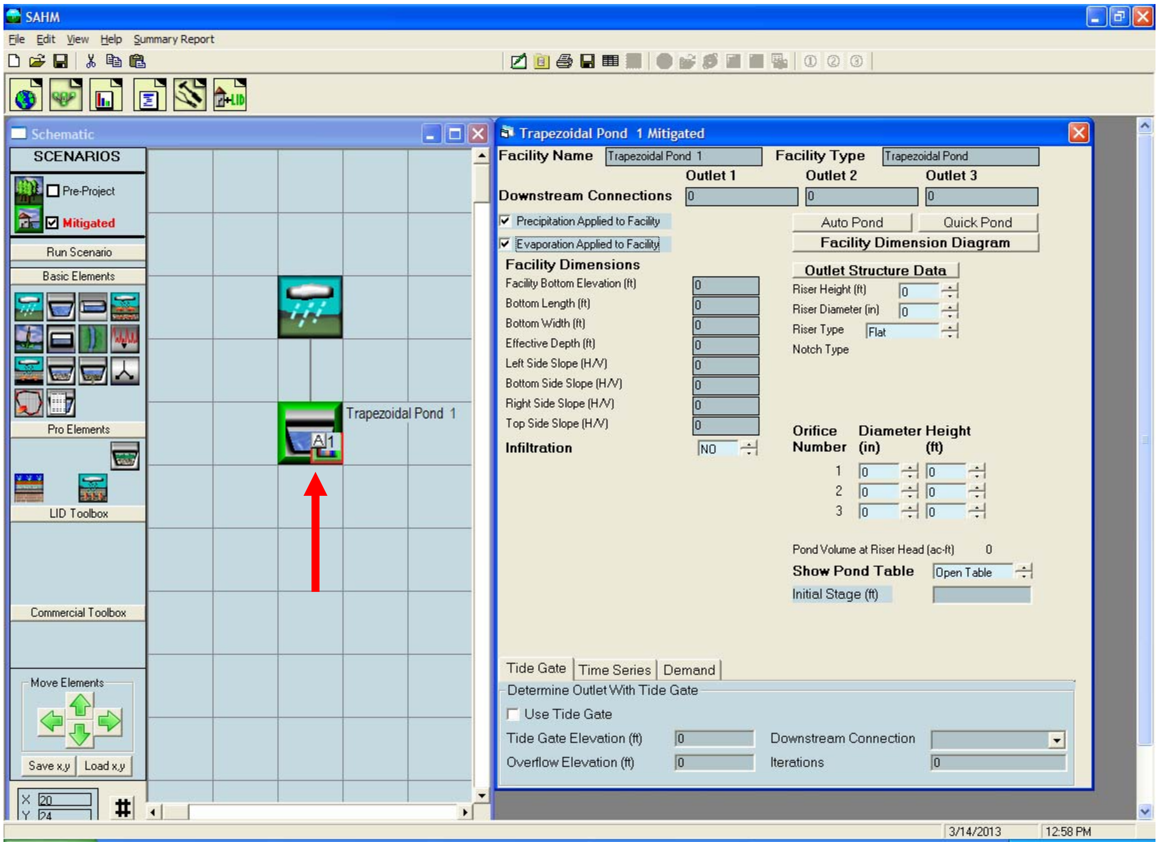
A line will connect the land use basin to the pond.



Right click on the trapezoidal pond element to connect the pond’s outlet to the point of compliance. Highlight Connect to Point Of Compliance and click.



The Point of Compliance screen will be shown for the pond. The pond has one outlet (by default). The outflow from the pond will be compared with the Pre-project runoff. The point of compliance is designated as POC 1 (SAHM allows for a maximum of 59 points of compliance in a single project). Click on the Connect button.

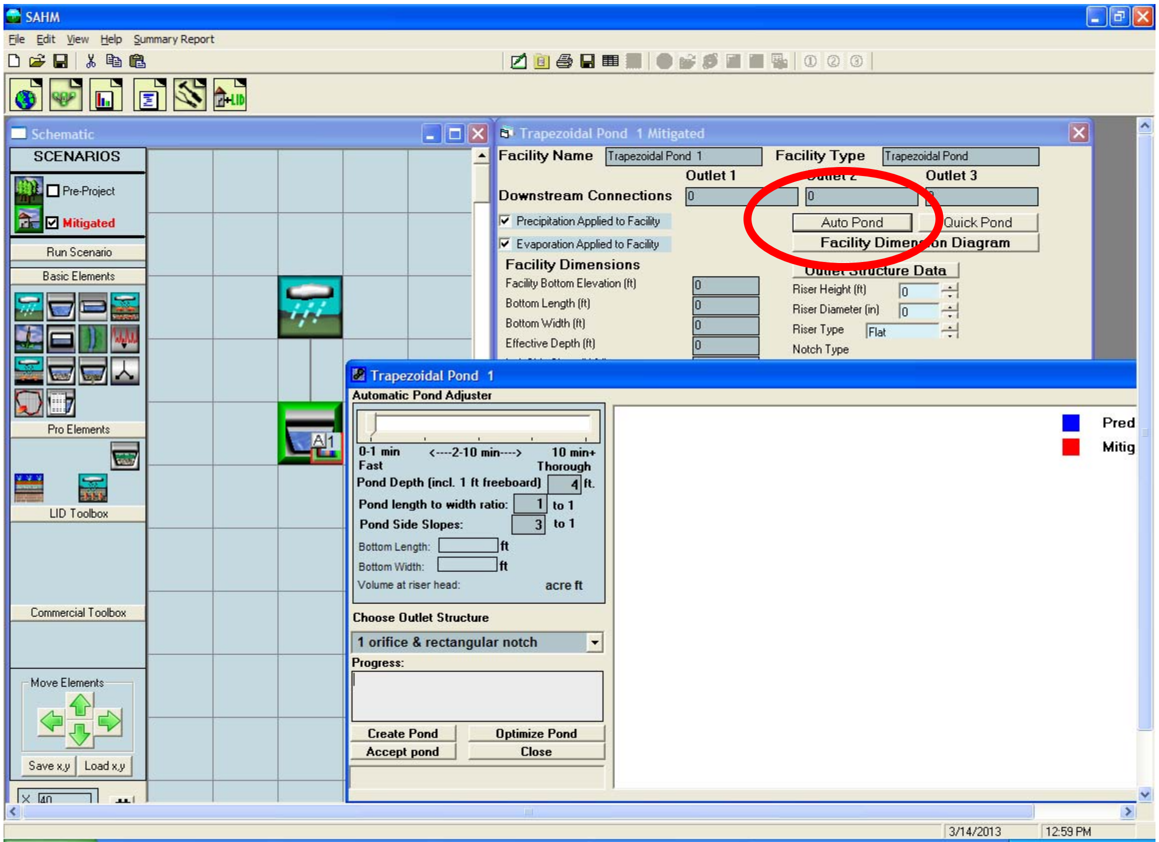


The point of compliance is shown on the pond element as a small box with the letter "A" and number 1 in the bar chart symbol in the lower right corner.

The letter "A" stands for Analysis and designates that this is an analysis location where flow and stage will be computed and the output flow and stage time series will be made available to the user. The number 1 denotes that this is POC 1.

You can have an analysis location without having a point of compliance at the same location, but you cannot have a point of compliance that is also not an analysis location.

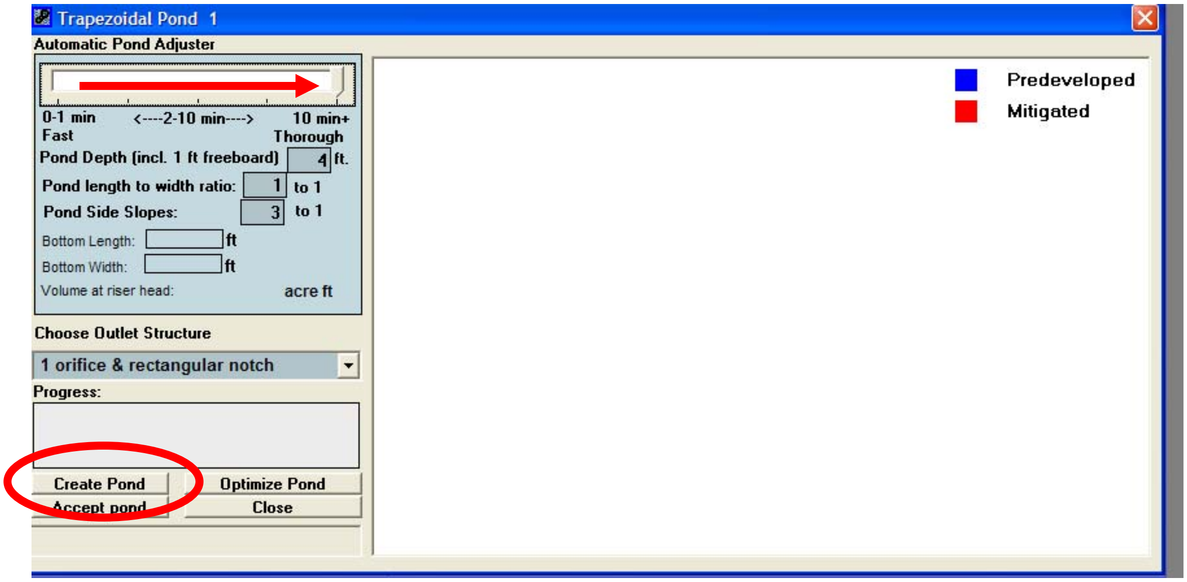
6. Sizing the pond.



A trapezoidal stormwater pond can be sized either manually or automatically (using Auto Pond). For this example Auto Pond will be used. (Go to page 52 to find more information about how to manually size a pond or other HMP facility.)

Click on the Auto Pond button and the Auto Pond screen will appear. The user can set the pond depth (default: 4 feet), pond length to width ratio (default: 1 to 1), pond side slopes (default: 3 to 1), and the outlet structure configuration (default: 1 orifice and riser with rectangular notch weir).

To optimize the pond design and create the smallest pond possible, move the Automatic Pond Adjuster pointer from the left to the right.



The pond does not yet have any dimensions. Click the Create Pond button to create initial pond dimensions, which will be the starting point for Auto Pond's automated optimization process to calculate the pond size and outlet structure dimensions.

Running Auto Pond automates the following SAHM processes:

1. the hourly Pre-project runoff is computed for the 30-50 years of record (it varies depending on the rain gage used),
2. the Pre-project runoff flood frequency is calculated based on the partial duration peak flows,
3. the range of flows is selected for the flow duration (lower threshold of 25% of the 2-year peak to the 10-year peak),
4. this flow range is divided into 100 increments, and
5. the number of hourly Pre-project flow values that exceed each flow increment level (Pre-project flow duration) are counted to create the flow duration curves and accompanying tabular results.

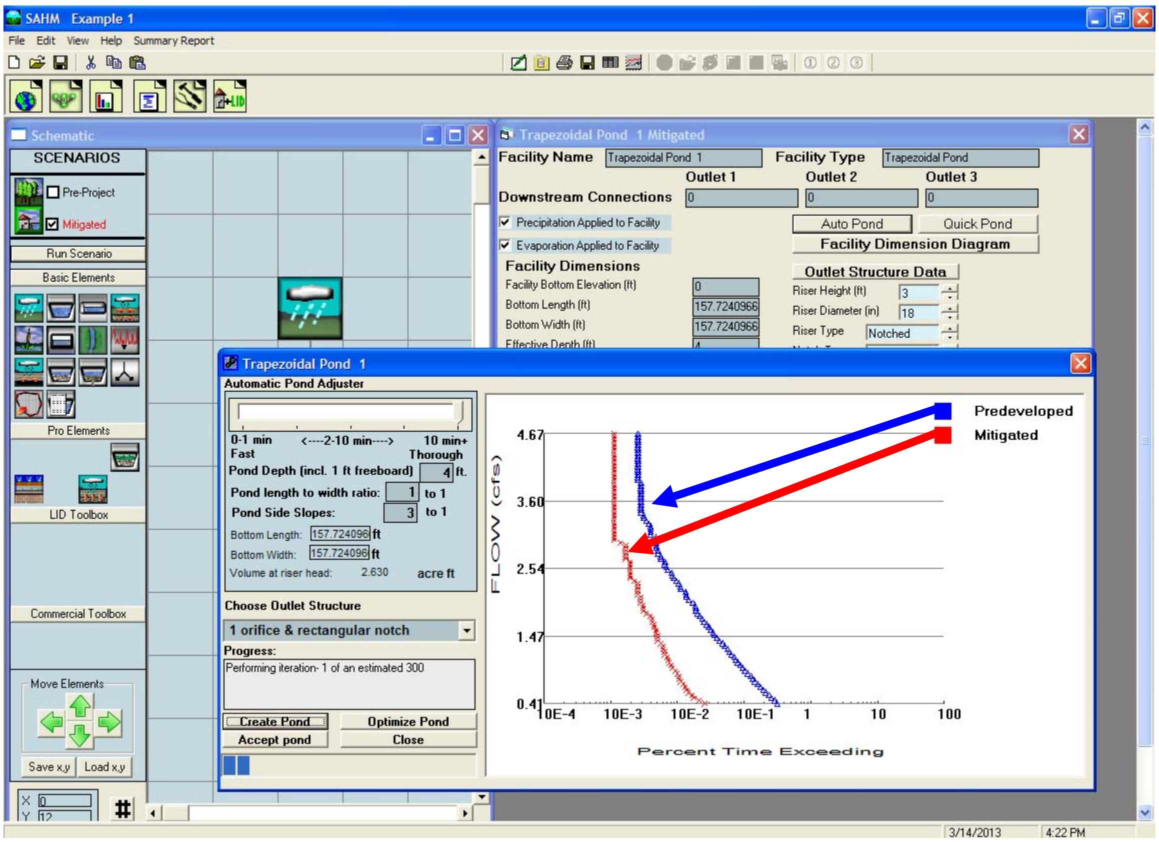
Next, SAHM computes the post-project runoff (in the Mitigated scenario) and routes the runoff through the pond. But before the runoff can be routed through the pond the pond must be given dimensions and an outlet configuration. Auto Pond uses a set of rules based on the Pre-project and Mitigated scenario land uses to give the pond an initial set of dimensions and an initial outlet orifice diameter and riser (the riser is given a default rectangular notch). This information allows SAHM to compute a stage-storage-discharge table for the pond.

With this initial pond stage-storage-discharge table SAHM:

1. routes the hourly post-project runoff through the pond for the 30-50 years of record to create to the Mitigated flow time series,

2. counts the number of hourly Mitigated flow values that exceed each flow increment level (this is the Mitigated flow duration), and
3. computes the ratio of Mitigated flow values to Pre-project flow values for each flow increment level (comparing the Pre-project and Mitigated flow duration results).

If any of the 100 individual ratio values is greater than allowed by the flow duration criteria then the pond fails to provide an appropriate amount of mitigation and needs to be resized.



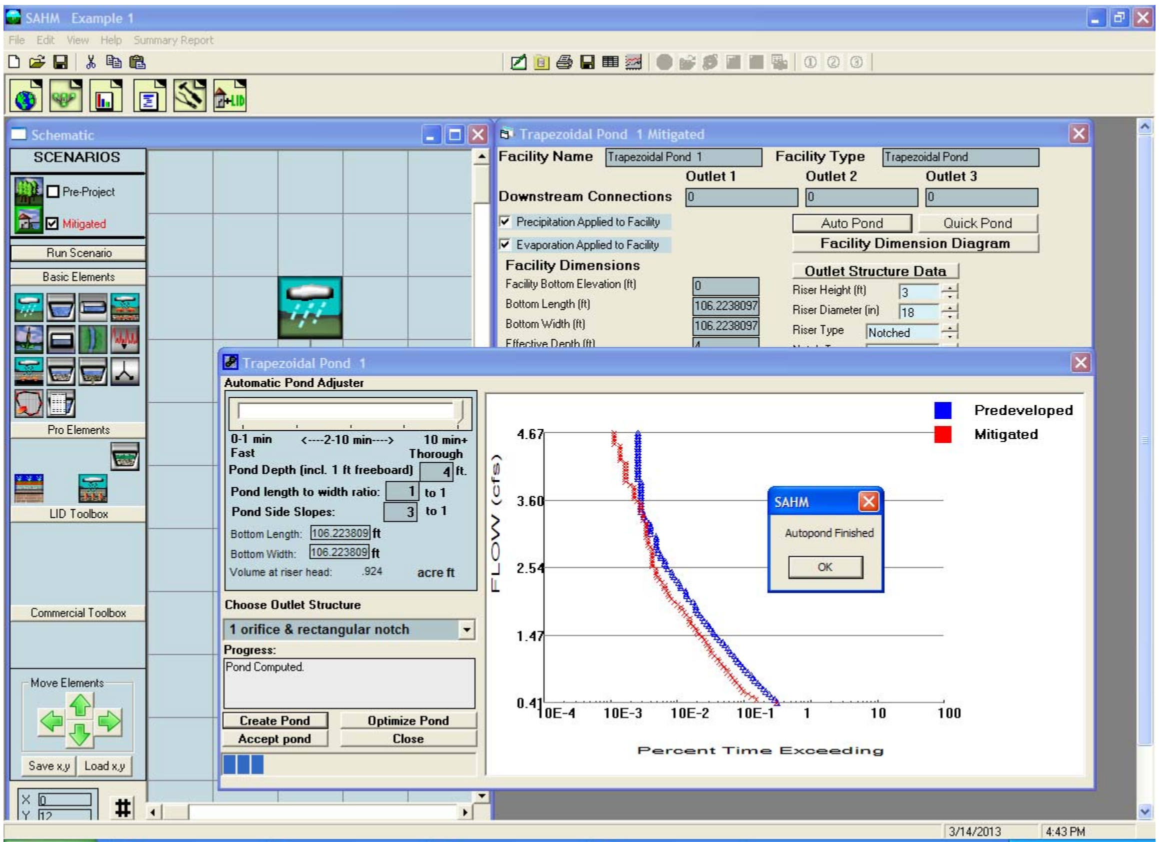
Flow duration results are shown in the plots above. The vertical axis shows the range of flows from 25% of the 2-year flow (0.41 cfs) to the 10-year flow (4.67 cfs). The horizontal axis is the percent of time that flows exceed a flow value. Plotting positions on the horizontal axis typical range from 0.001% to 1%, as explained below.

For the entire 30- to 50-year simulation period (depending on the period of record of the precipitation station used) all of the hourly time steps are checked to see if the flow for that time step is greater than the minimum flow duration criteria value (0.41 cfs, in this example). For a 50-year simulation period there are approximately 400,000 hourly values to check. Many of them are zero flows. The 25% of the Pre-project 2-year flow value is exceeded less than 1% of the total simulation period.

This check is done for both the Pre-project flows (shown in blue on the screen) and the Mitigated flows (shown in red).

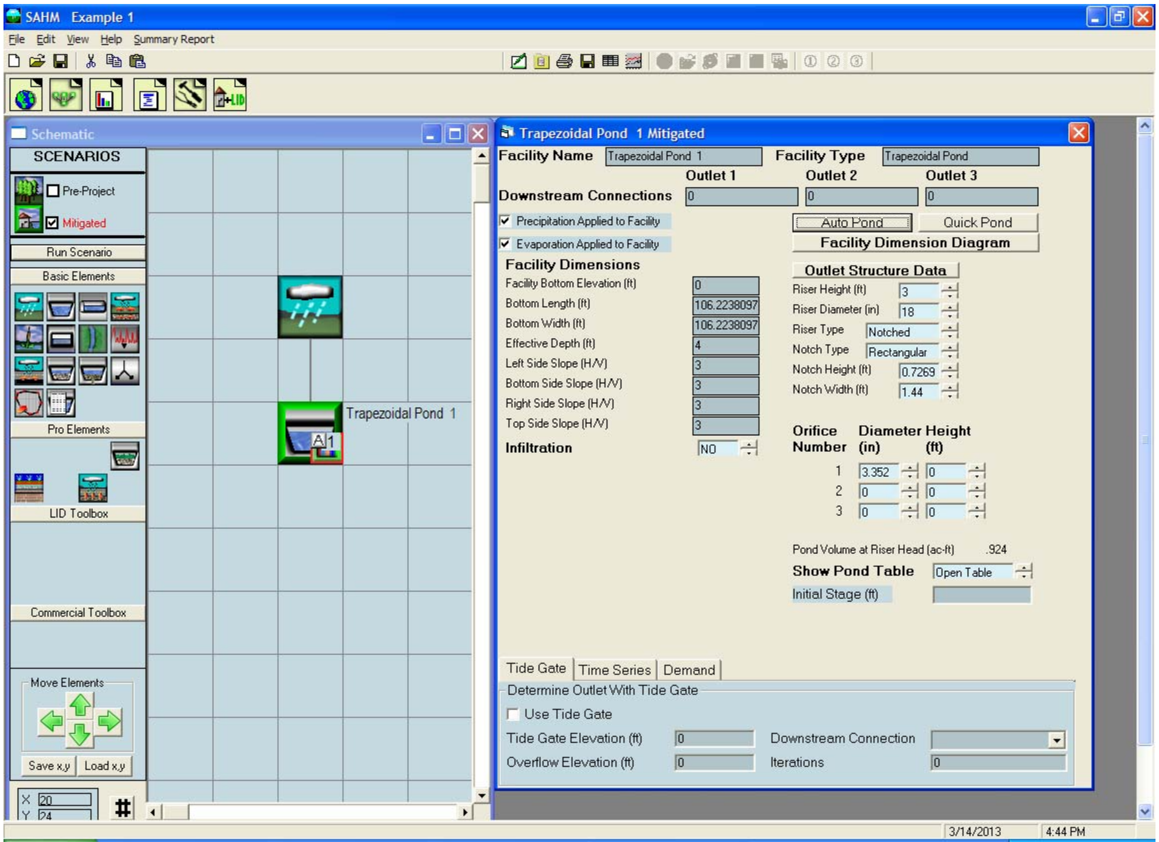
If all of the Mitigated flow duration values (in red) are to the left of the Pre-project flow duration values (in blue) then the pond mitigates the additional erosive flows produced by the development.

If the Mitigated flow duration values (in red) are far to the left of the Pre-project flow duration values (in blue) then the pond can be made smaller and still meet the flow duration criteria.



Auto Pond goes through an iteration process by which it changes the pond dimensions and outlet configuration, then instructs SAHM to again compute the resulting Mitigated runoff, compare flow durations, and decide if it has made the results better or worse. This iteration process continues until Auto Pond finally concludes that an optimum solution has been found and the Mitigated flow duration values (in red) are as close as possible to the Pre-project flow duration values (in blue).

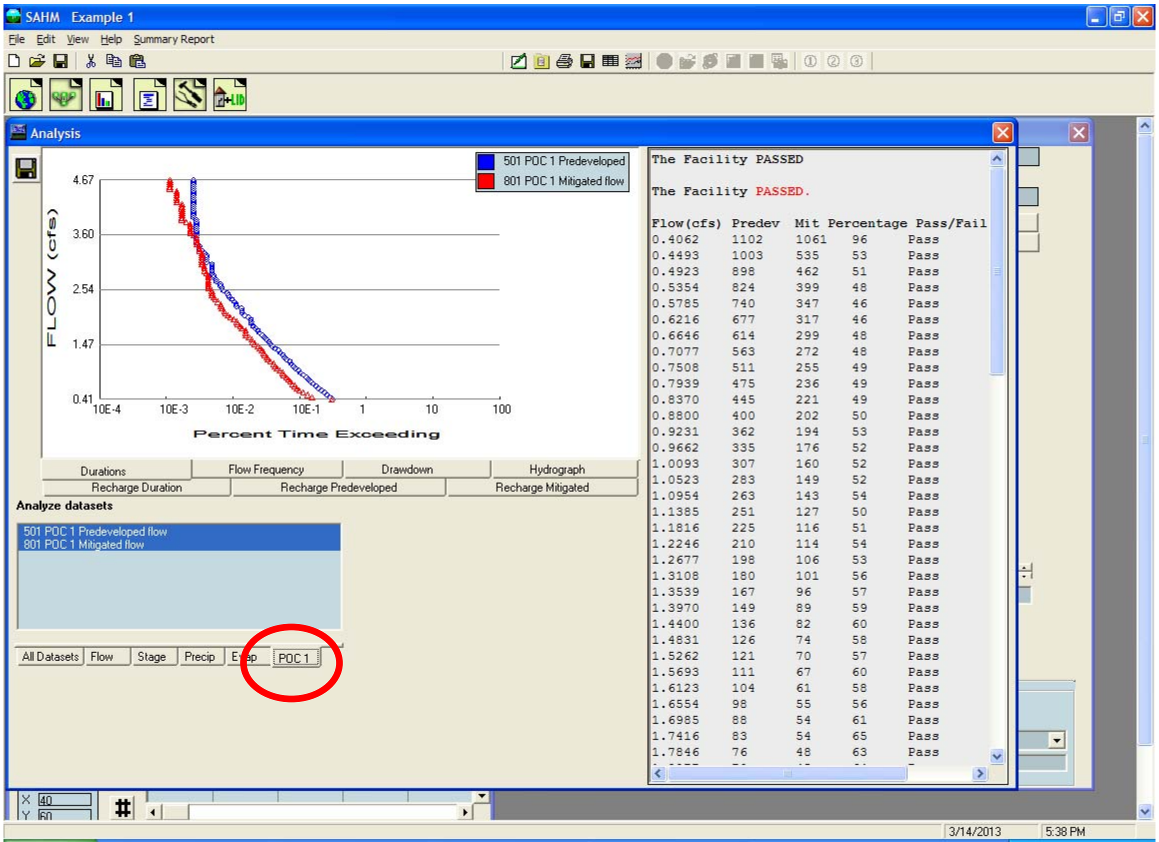
The user may continue to manually optimize the pond by manually changing pond dimensions and/or the outlet structure configuration. (Manual optimization is explained in more detail on page 52.) After making these changes the user should click on the Optimize Pond button to check the results and see if Auto Pond can make further improvements.



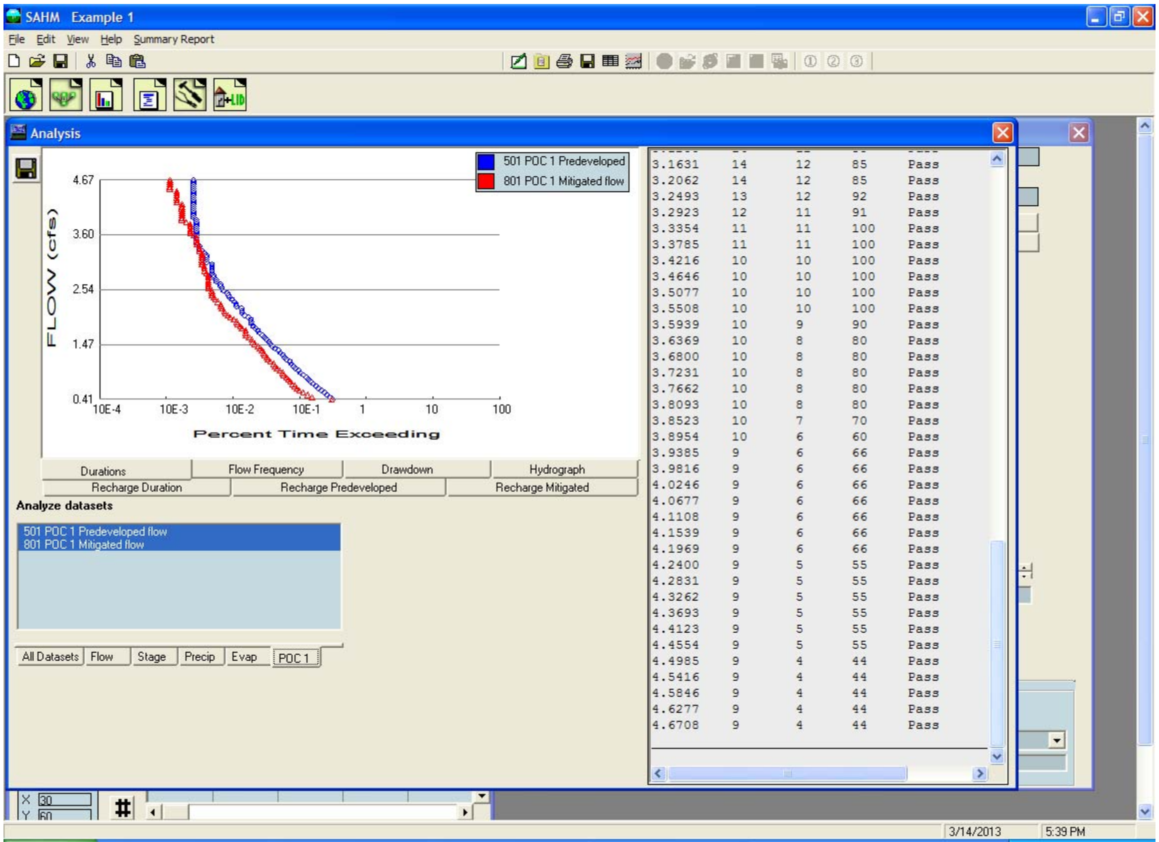
The final pond dimensions (bottom length, bottom width, effective pond depth, and side slopes) and outlet structure information (riser height, riser diameter, riser weir type, weir notch height and width, and orifice diameter and height) are shown on the trapezoidal pond screen to the right of the Schematic grid.

NOTE: If Auto Pond selects a bottom orifice diameter smaller than the smallest diameter allowed by the local municipal permitting agency then the user has the option of specifying a minimum allowable bottom orifice diameter even if this size diameter is too large to meet flow duration criteria for this element. Additional mitigating BMPs may be required to meet local hydromodification control requirements. Please see Appendix C or consult with local municipal permitting agency for more details. For manual sizing information see page 52.

7. Review analysis.

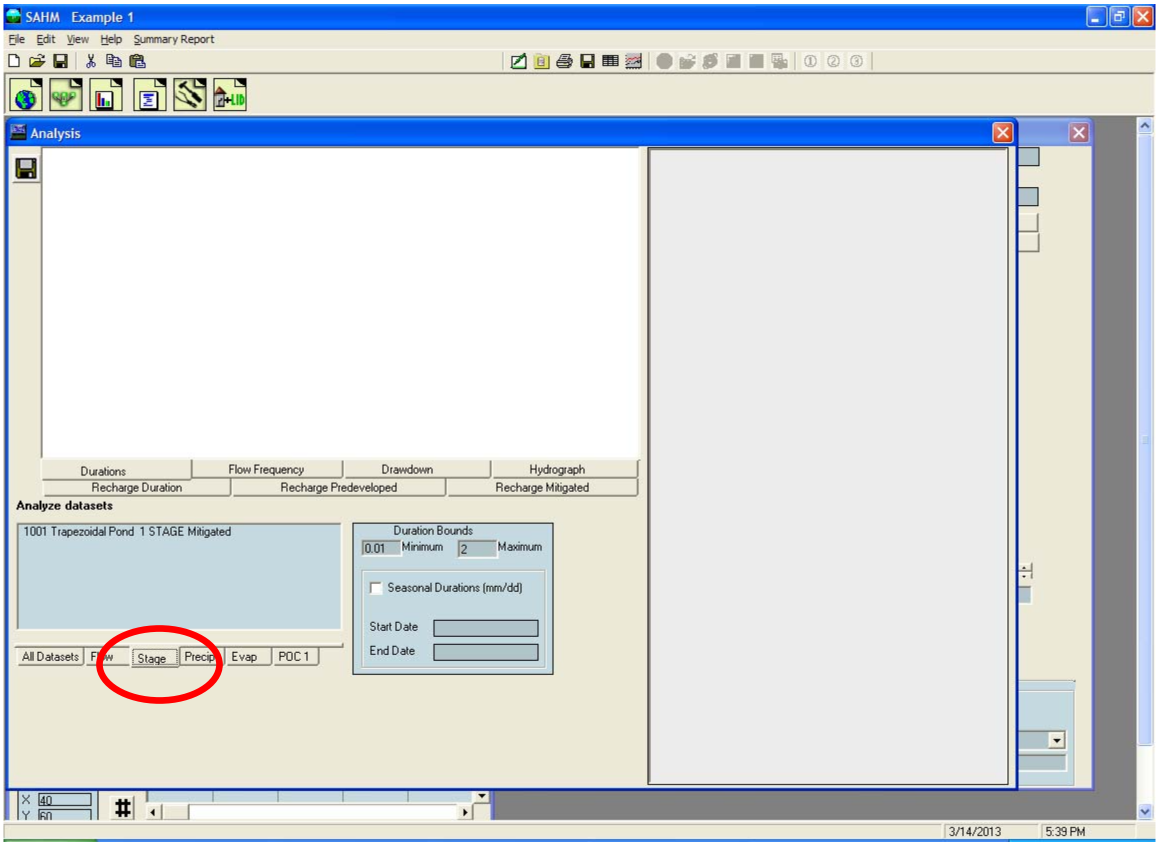


The Analysis tool bar button (third from the left) brings up the Analysis screen where the user can look at the results. Each time series dataset is listed in the Analyze Datasets box in the lower left corner. To review the flow duration analysis at the point of compliance select the POC 1 tab at the bottom and make sure that both the 501 POC 1 Pre-project flow and 801 POC 1 Developed flow are highlighted.



The flow duration plot for both Pre-project and Mitigated flows will be shown along with the specific flow values and number of times Pre-project and Mitigated flows exceeded those flow values. The Pass/Fail on the right indicates whether or not at that flow level the flow control standard criteria were met and the pond passes at that flow level (in this example from 25% of the 2-year flow to the 10-year). If not, a Fail is shown; a single Fail fails the pond design.

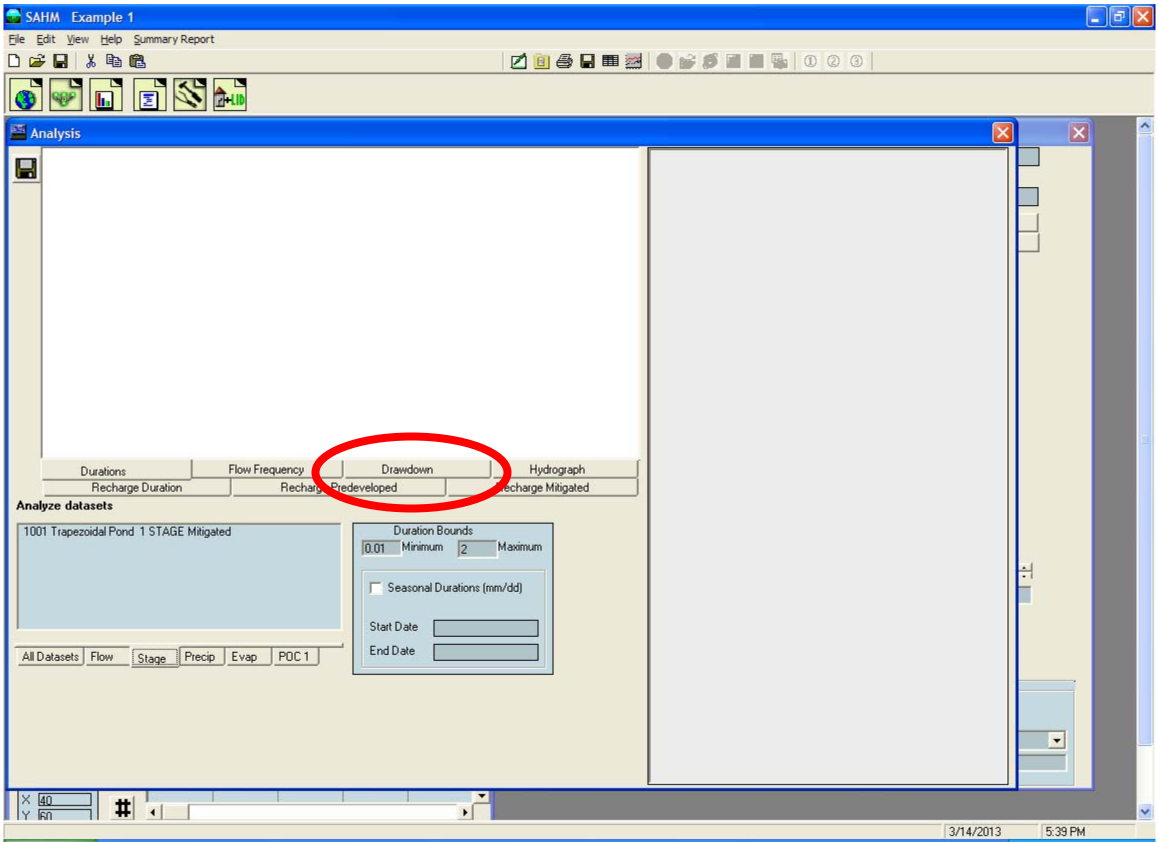
A maximum ratio of 110% is allowed for flows between the lower and upper thresholds for no more than 10 of the 100 flow levels listed in the flow duration table on the right of the flow duration plot.



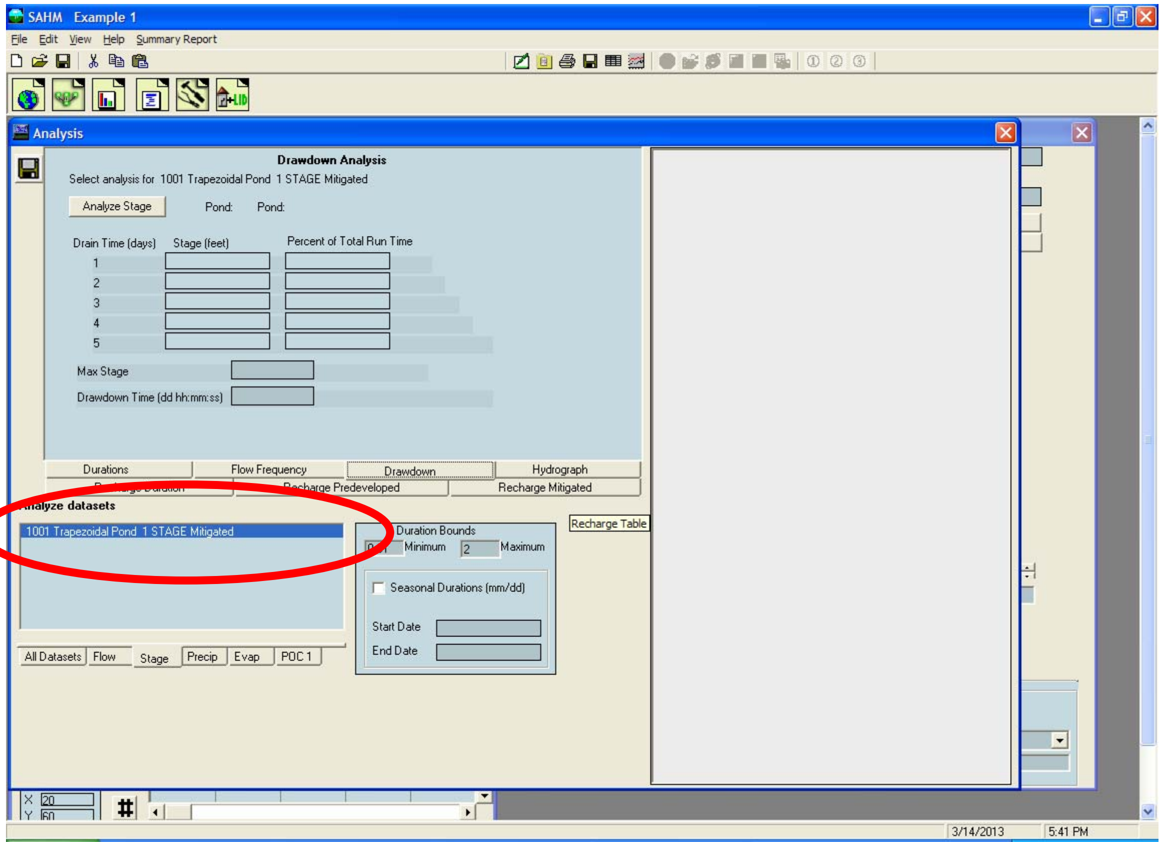
Pond drawdown/retention time is computed on the Analysis screen.

NOTE: This information is not required for basic sizing of the flow duration facility, but can assist the user in determining the overall suitability of the mitigated design in meeting additional, related requirements for treating stormwater runoff and minimizing risk of vector (mosquito) breeding problems. See page 109 for more descriptions of this SAHM feature, and Appendix C for discussion and references for these requirements.

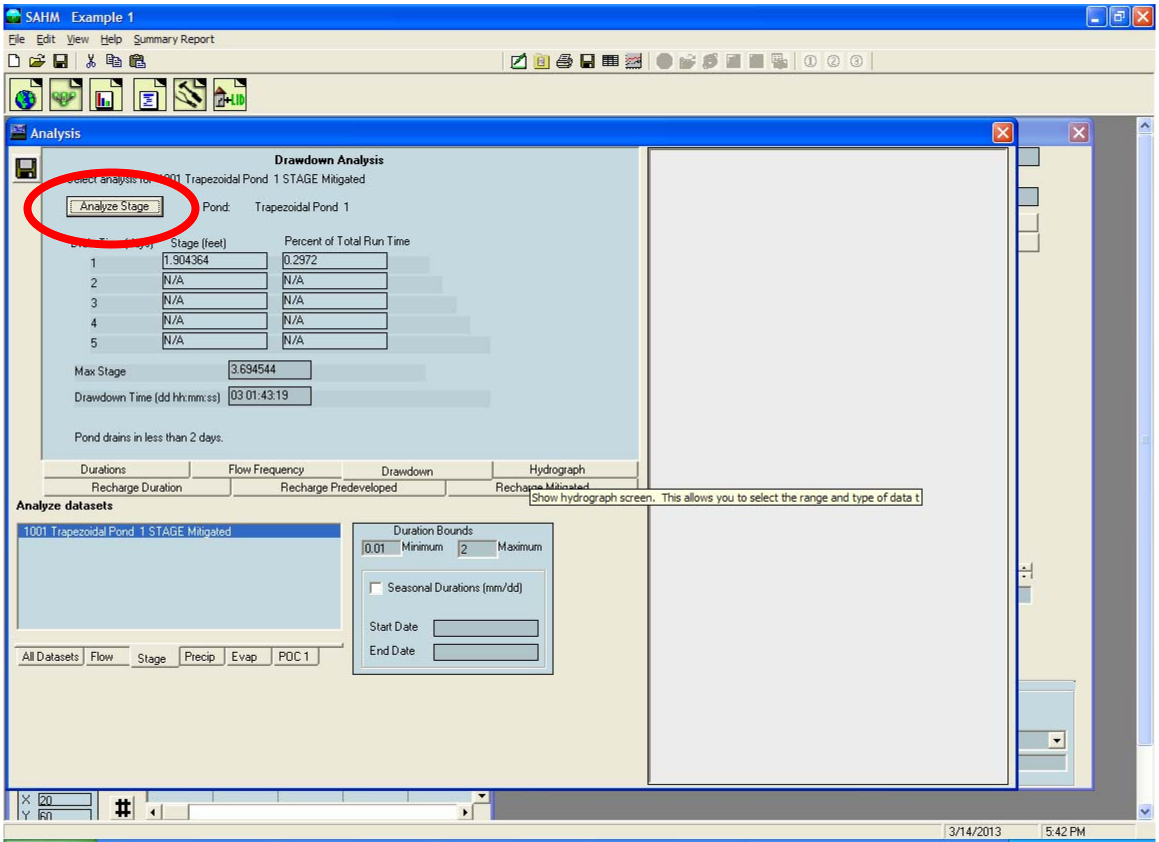
Click on the Stage tab at the bottom to get the Mitigated pond stage time series.



Click on the tab labeled Drawdown. This is where the pond drawdown/retention time results will be shown.



Select the pond you want to analyze for drawdown/retention time (in this example there is only one pond: Trapezoidal Pond 1) by clicking on the dataset and highlighting it.



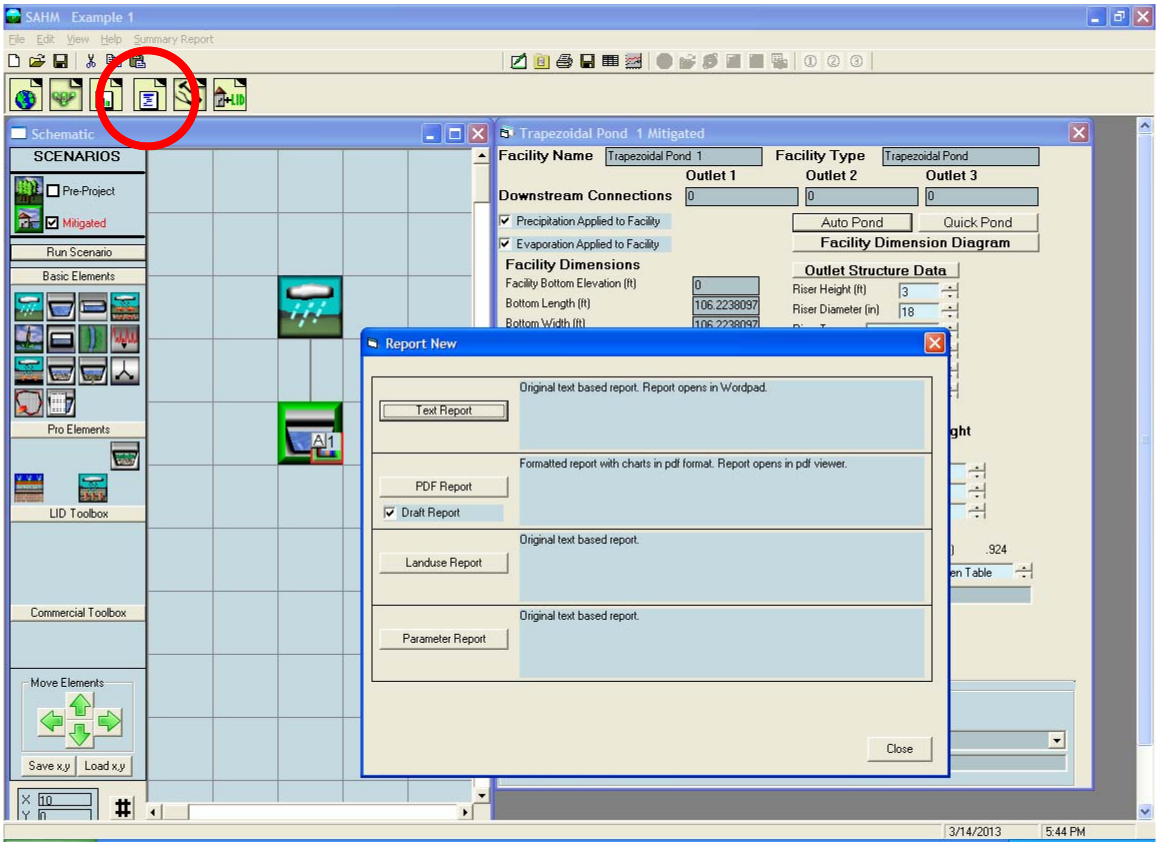
Click on the Analyze Stage button and the computed pond stages (pond water depths) are summarized and reported in terms of drain/retention time (in days).

For this example, the maximum stage computed during the entire 30-50 year simulation period is 3.69 feet. This maximum stage has a drawdown time of approximately 3 days, 1 hour, 43 minutes.

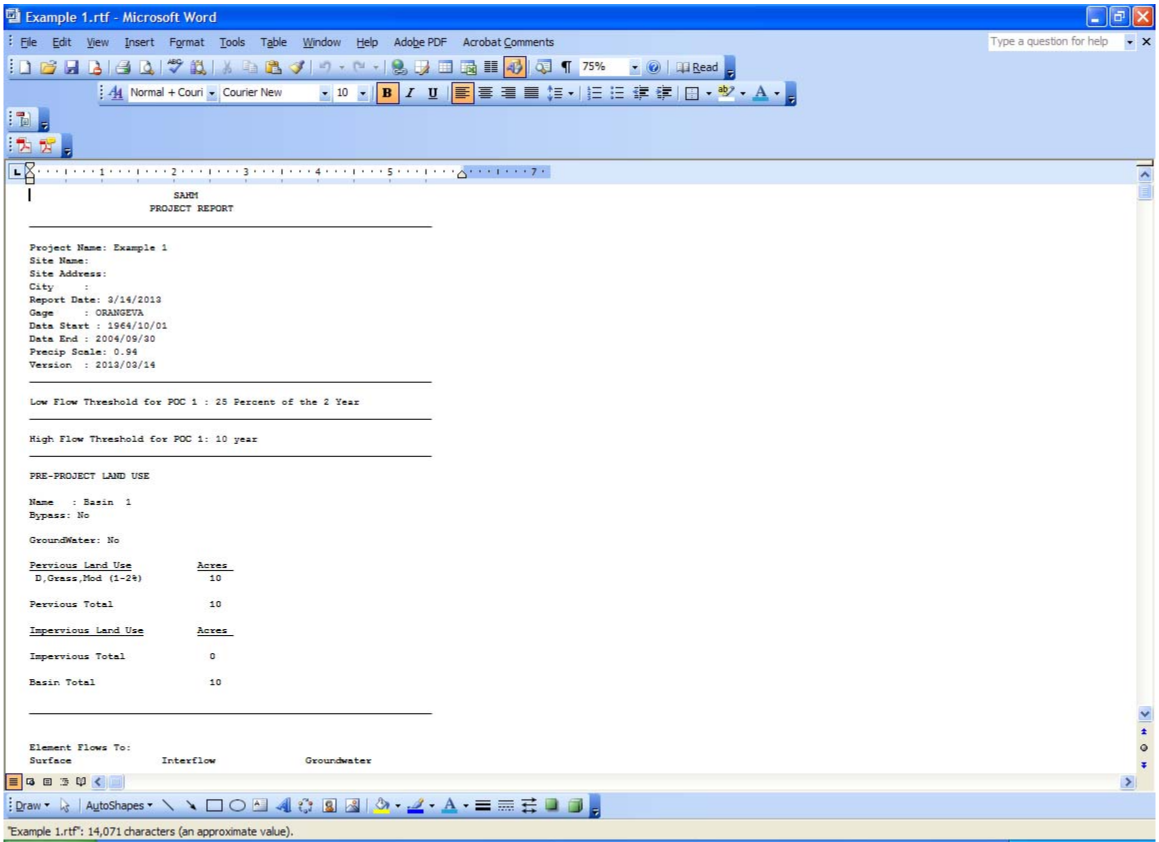
Ponds may have drain times in excess of the allowed maximum of hours. This can occur when a pond has a small bottom orifice. If this is not acceptable then the user needs to change the pond outlet configuration, manually run the Mitigated scenario, and repeat the analyze stage computations. A situation may occur where it is not possible to have both an acceptable pond drawdown/ retention time and meet the flow duration criteria.

NOTE: See Appendix C or the local municipal permitting agency for an overview of other requirements that may apply regarding drawdown time, and suggestions for addressing situations where it is not possible to meet all drawdown/retention time guidelines and also meet the flow duration criteria. The guidance documentation assumes that the flow duration criteria take precedence unless the user is instructed otherwise by the local municipal permitting agency.

8. Produce report.

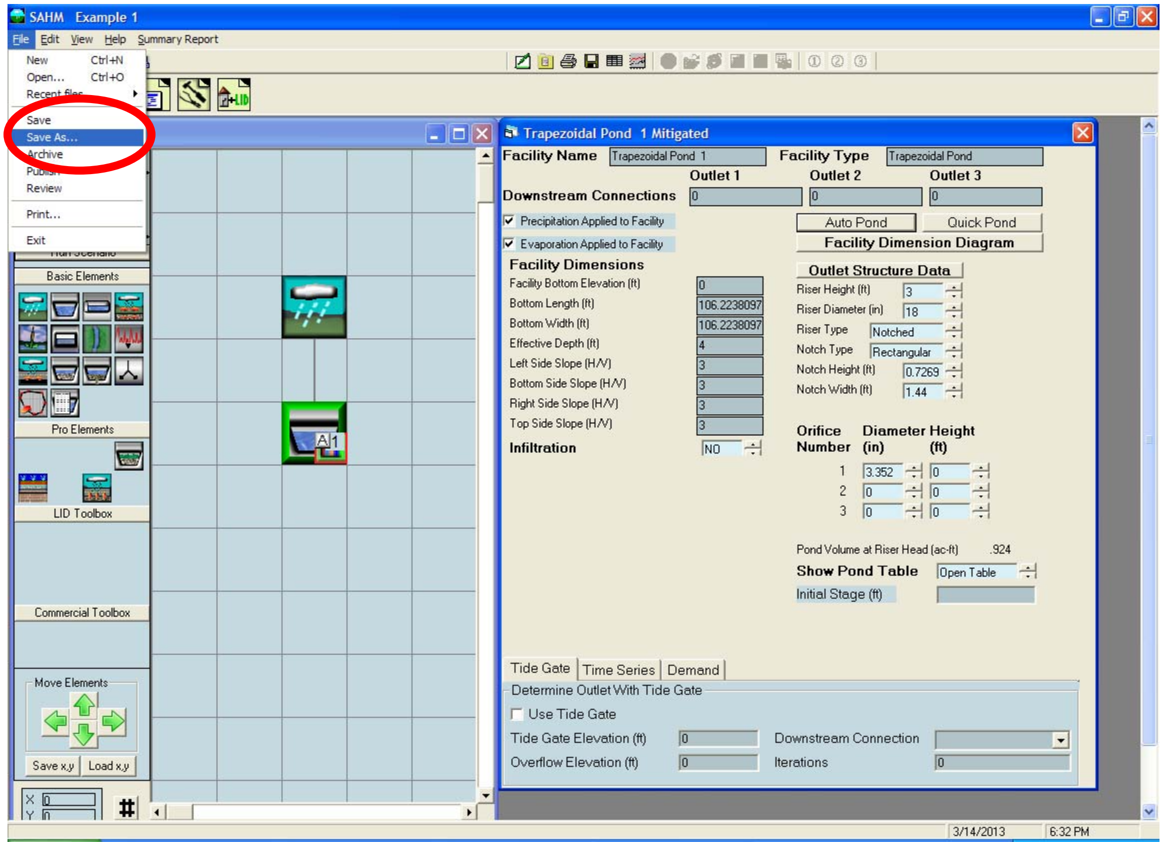


Click on the Reports tool bar button (fourth from the left) to select the Report options table. Selecting Text Report will generate a project report in Microsoft Word RTF format with all of the project information and results. Selecting PDF Report will generate a project report in Adobe Acrobat PDF format with all of the project information and results. The Landuse Report produces a list of the land use information contained in the project. The Parameter Report lists any HSPF parameter value changes made by the user.

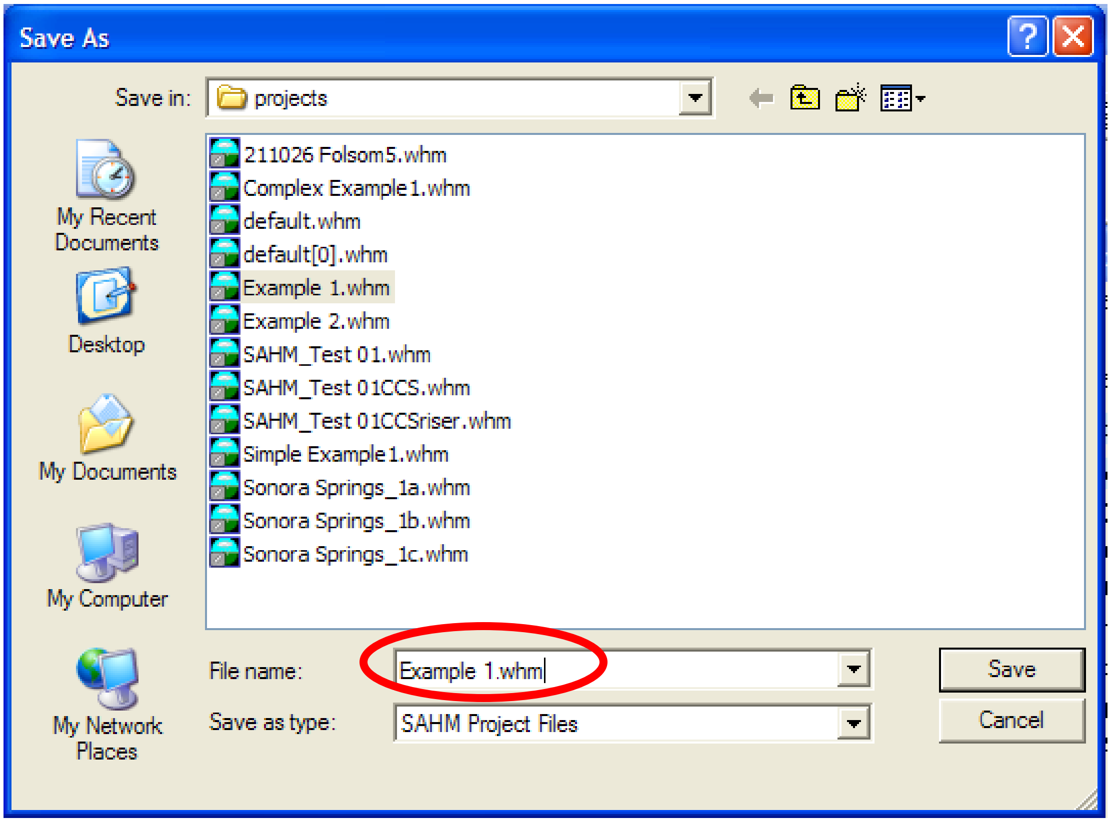


Scroll down the Text Report or the PDF Report screen to see all of the results.

9. Save project.

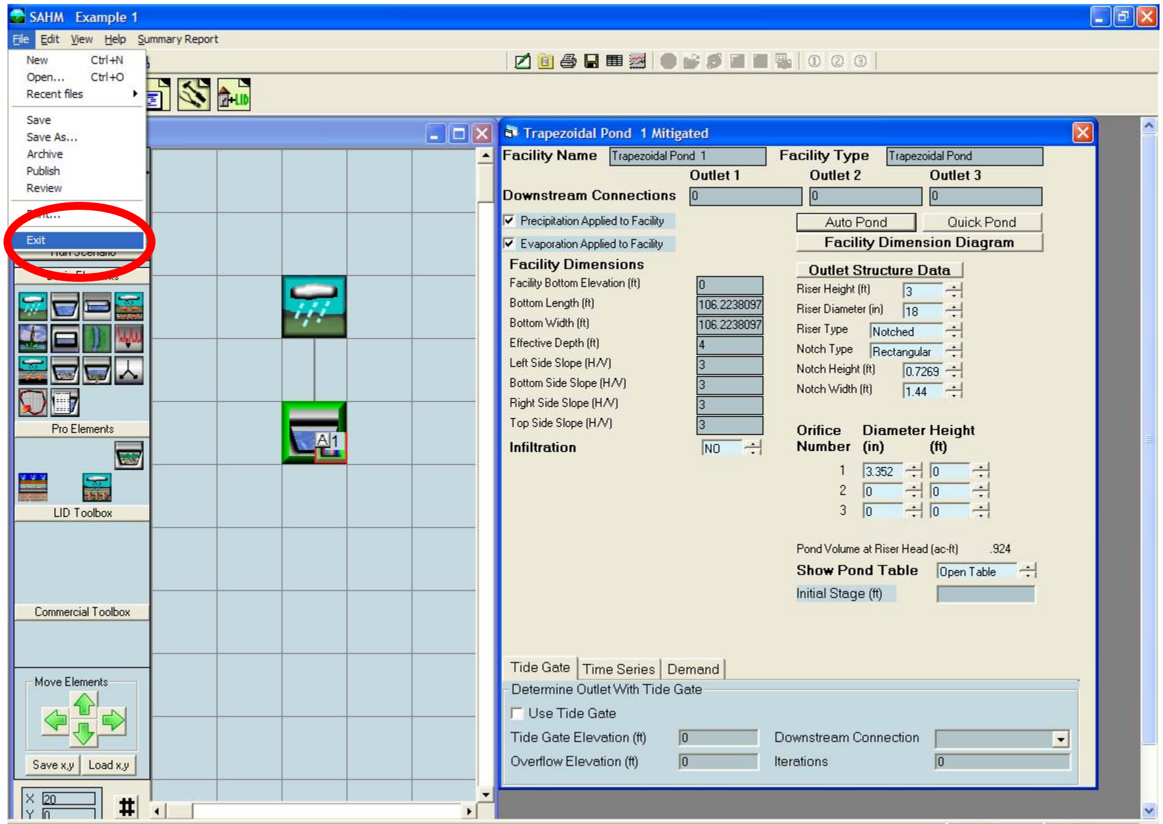


To save the project click on File in the upper left corner and select Save As.



Select a file name and save the SAHM project file. The user can exit SAHM and later reload the project file with all of its information by going to File, Open.

10. Exit SAHM.



To exit SAHM click on File in the upper left corner and select Exit. Or click on the X in the red box in the upper right hand corner of the screen.

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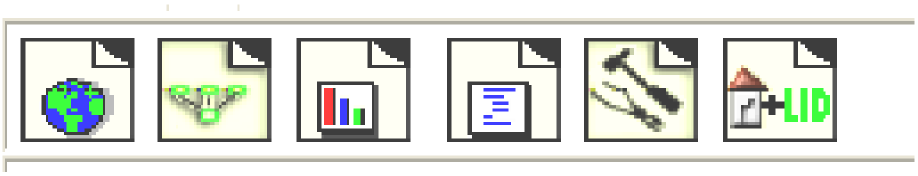
MAIN SCREENS



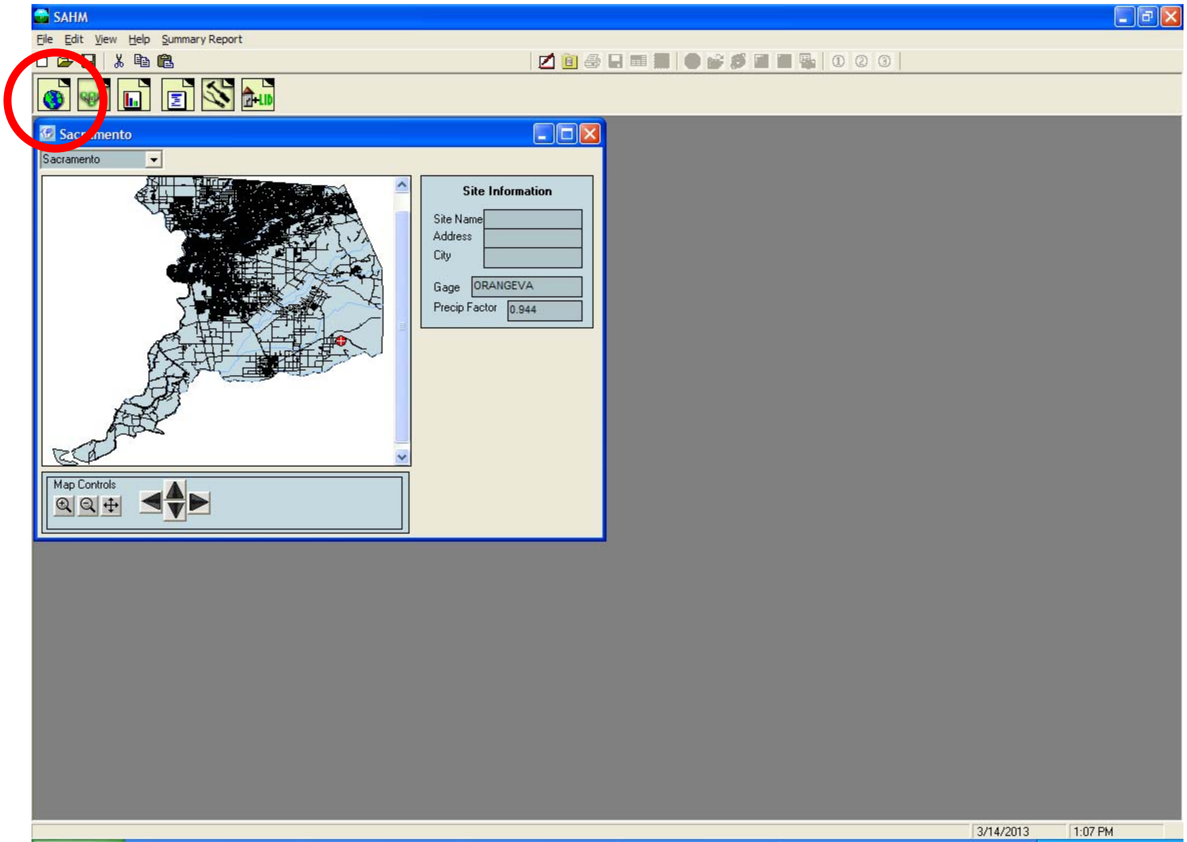
SAHM has six main screens. These main screens can be accessed through the buttons shown on the tool bar above or via the View menu.

The six main screens are:

- Map Information
- General Project Information
- Analysis
- Reports
- Tools
- LID (Low Impact Development) Analysis

Each is discussed in more detail in the following sections.

MAP INFORMATION SCREEN



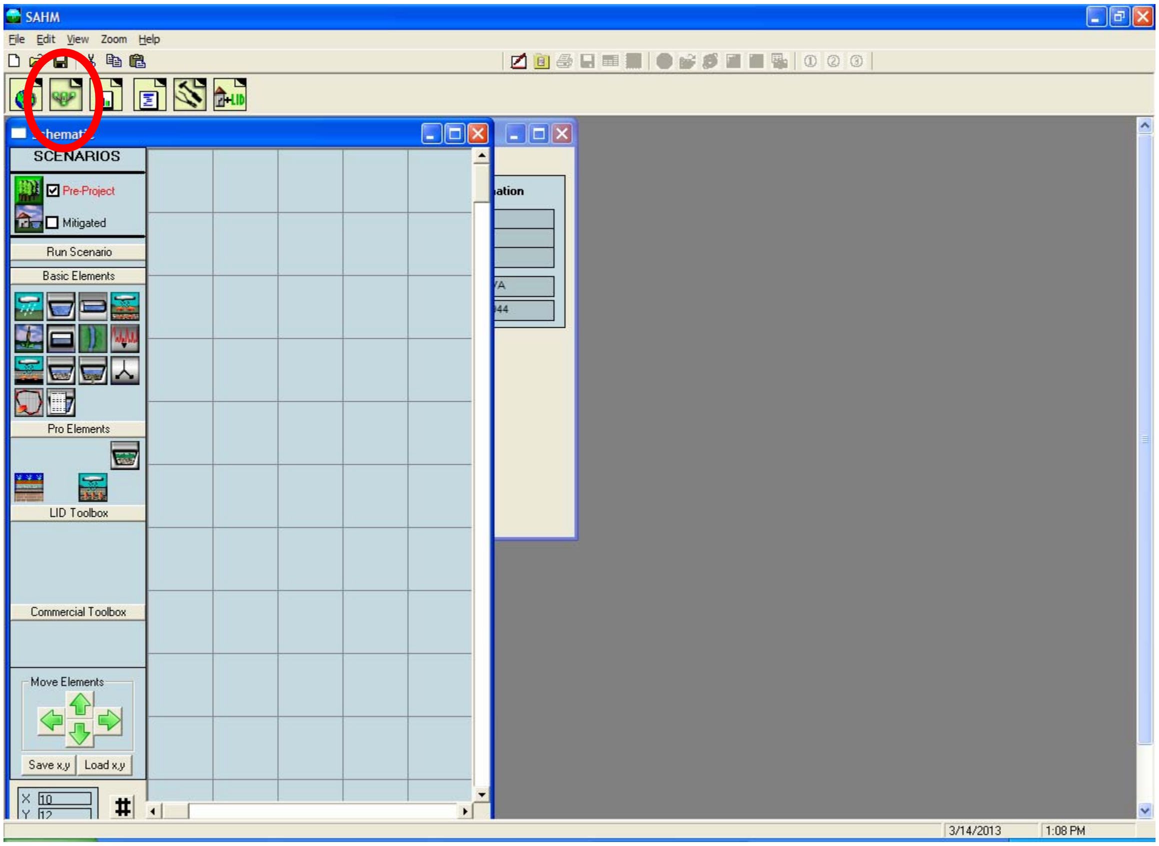
The Map Screen contains county information. The precipitation gage and precip factor are shown to the right of the map. They are based on the project site location.

SAHM selects the appropriate rain gage record and precipitation multiplication factor for the project site from the available long-term hourly precipitation records provided by Sacramento County. Sacramento County has four long-term hourly precipitation records: Elk Grove, Natomas, Orangevale, and Rancho Cordova. These long-term hourly precipitation records and corresponding evaporation records are also used in the Sacramento BMP Sizing Calculator.

The user can provide site information (optional). The site name and address will help to identify the project on the Report screen and in the printed report provided to the local municipal permitting agency.

The user locates the project site on the map screen by using the mouse and left clicking at the project site location. Right clicking on the map re-centers the view. The + and – buttons zoom in and out, respectively. The cross hair button zooms out to the full county view. The arrow keys scroll the map view.

GENERAL PROJECT INFORMATION SCREEN



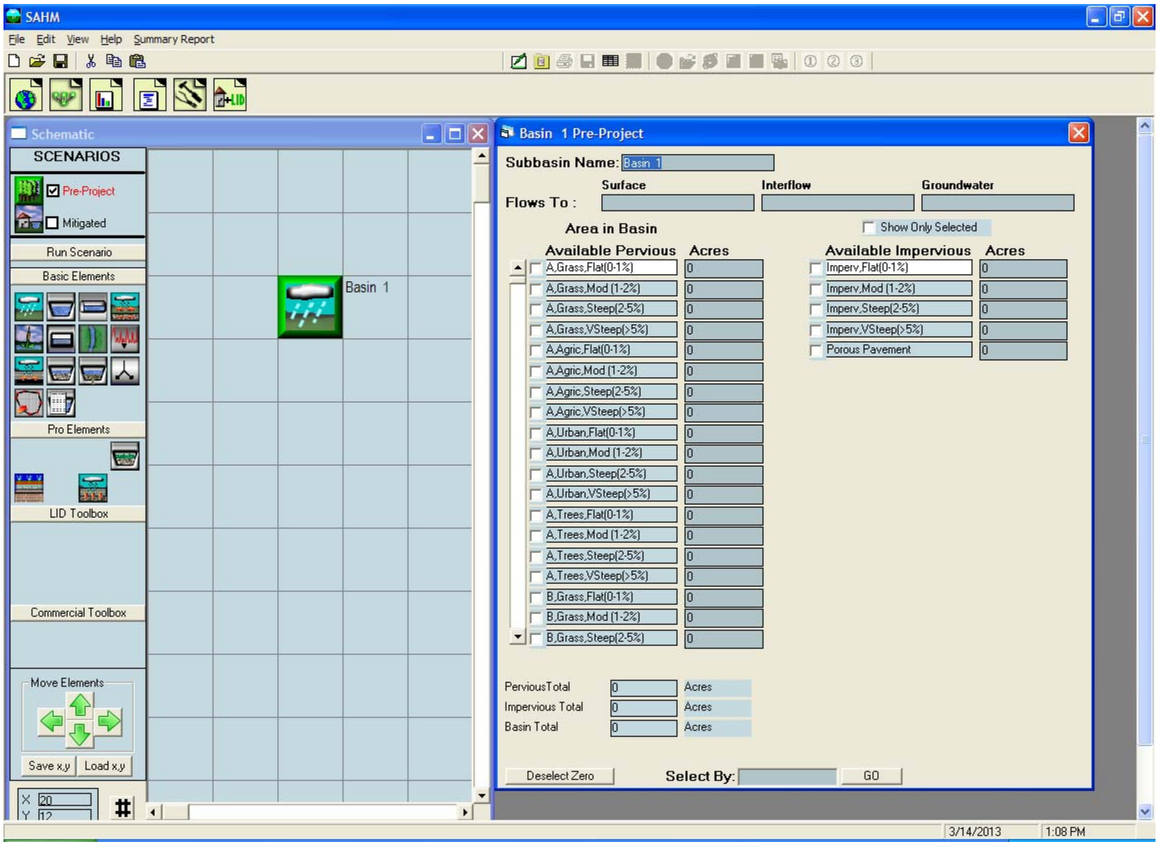
The project screen contains all of the information about the project site for the two land use scenarios: Pre-project land use conditions and the Mitigated (developed) land use conditions. To change from one scenario to another check the box in front of the scenario name in the upper left corner of the screen.

Pre-project is defined as the existing land cover conditions prior to any new land use development. Runoff from the Pre-project scenario is used as the target for the Mitigated scenario compliance. The model will accept any land use for this scenario.

Mitigated is defined as the developed land use with mitigation measures (as selected by the user). Mitigated is used for sizing stormwater control and water quality facilities. The runoff from the Mitigated scenario is compared with the Pre-project scenario runoff to determine compliance with flow duration criteria.

Below the scenario boxes are the Elements. Each element represents a specific feature (basin, pond, etc.) and is described in more detail in the following section.

SCHEMATIC EDITOR



The project screen also contains the Schematic Editor. The Schematic Editor is the grid to the right of the elements. This grid is where each element is placed and linked together. The grid, using the scroll bars on the left and bottom, expands as large as needed to contain all of the elements for the project.

All movement on the grid must be from the top of the grid down.

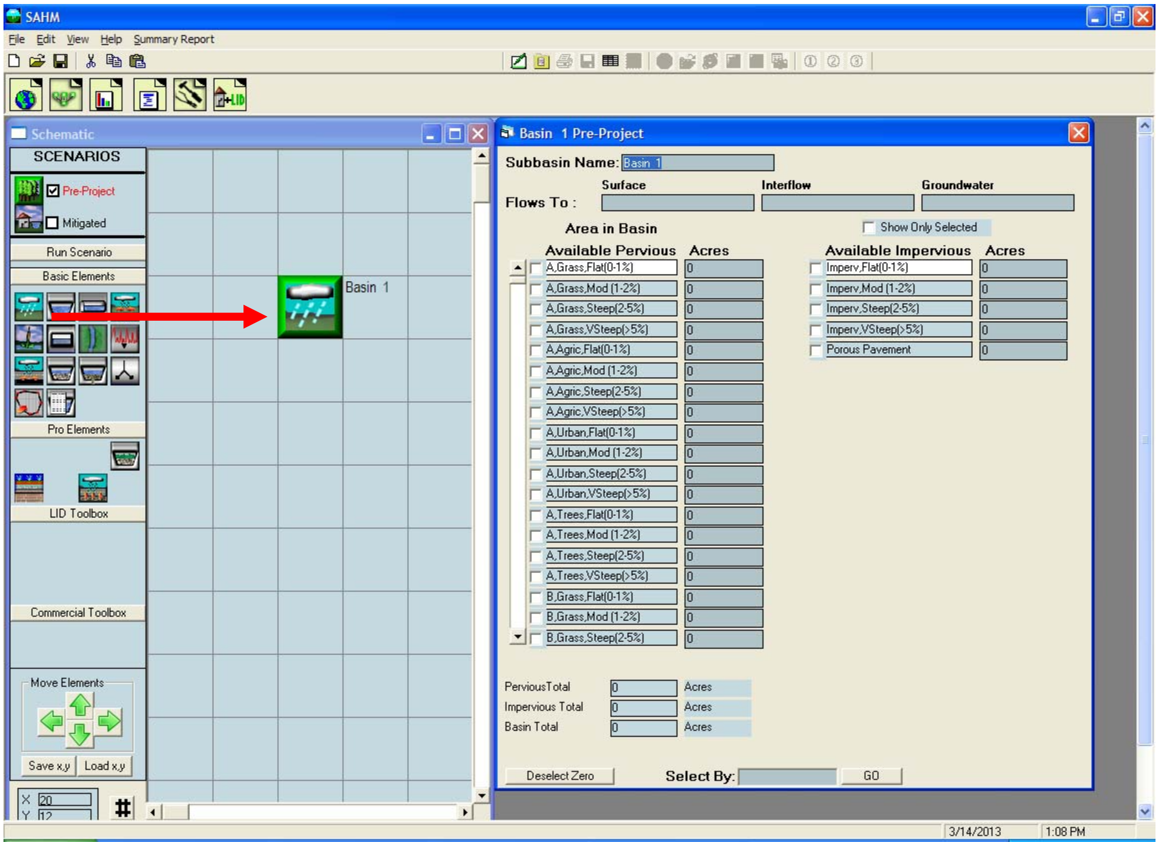
The space to the right of the grid will contain the appropriate element information.

To select and place an element on the grid, first left click on the specific element in the Elements menu and then drag the element to the selected grid square. The selected element will appear in the grid square.

The entire grid can be moved up, down, left, or right using the Move Elements arrow buttons.

The grid coordinates from one project can be saved (Save x,y) and used for new projects (Load x,y).

BASIN ELEMENT



The Basin element represents a drainage area that can have any combination of soils, land cover, and land slopes. A basin produces three types of runoff: (1) surface runoff, (2) interflow, and (3) groundwater.

Surface runoff is defined as the overland flow that quickly reaches a conveyance system. Surface runoff mainly comes from impervious surfaces.

Interflow is shallow, subsurface flow produced by pervious land categories and varies based on soil characteristics and how these characteristics are altered by land development practices.

Groundwater is the subsurface flow that typically does not enter a stormwater conveyance system, but provides base flow directly to streams and rivers.

The user can specify where each of these three types of runoff should be directed. The default setting is for the surface runoff and interflow to go to the stormwater facility; groundwater should not be connected unless there is observed base flow occurring in the drainage basin.

Table 1 shows the different pervious land types represented in the Basin element.

Table 1. SAHM Pervious Land Types

PERLND No.	Soil Type	Land Cover	Land Slope
1	A	Grass	Flat (0-1%)
2	A	Grass	Moderate (1-2%)
3	A	Grass	Steep (2-5%)
4	A	Grass	Very Steep (>5%)
5	A	Agricultural	Flat (0-1%)
6	A	Agricultural	Moderate (1-2%)
7	A	Agricultural	Steep (2-5%)
8	A	Agricultural	Very Steep (>5%)
9	A	Urban	Flat (0-1%)
10	A	Urban	Moderate (1-2%)
11	A	Urban	Steep (2-5%)
12	A	Urban	Very Steep (>5%)
13	A	Trees	Flat (0-1%)
14	A	Trees	Moderate (1-2%)
15	A	Trees	Steep (2-5%)
16	A	Trees	Very Steep (>5%)
17	B	Grass	Flat (0-1%)
18	B	Grass	Moderate (1-2%)
19	B	Grass	Steep (2-5%)
20	B	Grass	Very Steep (>5%)
21	B	Agricultural	Flat (0-1%)
22	B	Agricultural	Moderate (1-2%)
23	B	Agricultural	Steep (2-5%)
24	B	Agricultural	Very Steep (>5%)
25	B	Urban	Flat (0-1%)
26	B	Urban	Moderate (1-2%)
27	B	Urban	Steep (2-5%)
28	B	Urban	Very Steep (>5%)
29	B	Trees	Flat (0-1%)
30	B	Trees	Moderate (1-2%)
31	B	Trees	Steep (2-5%)
32	B	Trees	Very Steep (>5%)
33	C	Grass	Flat (0-1%)
34	C	Grass	Moderate (1-2%)
35	C	Grass	Steep (2-5%)
36	C	Grass	Very Steep (>5%)
37	C	Agricultural	Flat (0-1%)
38	C	Agricultural	Moderate (1-2%)
39	C	Agricultural	Steep (2-5%)
40	C	Agricultural	Very Steep (>5%)
41	C	Urban	Flat (0-1%)
42	C	Urban	Moderate (1-2%)
43	C	Urban	Steep (2-5%)

44	C	Urban	Very Steep (>5%)
45	C	Trees	Flat (0-1%)
46	C	Trees	Moderate (1-2%)
47	C	Trees	Steep (2-5%)
48	C	Trees	Very Steep (>5%)
49	D	Grass	Flat (0-1%)
50	D	Grass	Moderate (1-2%)
51	D	Grass	Steep (2-5%)
52	D	Grass	Very Steep (>5%)
53	D	Agricultural	Flat (0-1%)
54	D	Agricultural	Moderate (1-2%)
55	D	Agricultural	Steep (2-5%)
56	D	Agricultural	Very Steep (>5%)
57	D	Urban	Flat (0-1%)
58	D	Urban	Moderate (1-2%)
59	D	Urban	Steep (2-5%)
60	D	Urban	Very Steep (>5%)
61	D	Trees	Flat (0-1%)
62	D	Trees	Moderate (1-2%)
63	D	Trees	Steep (2-5%)
64	D	Trees	Very Steep (>5%)

The user does not need to know or keep track of the HSPF PERLND number. That number is used only for internal tracking purposes.

The user inputs the number of acres of appropriate basin land use information. Pervious land use information is in the form of soil, land cover, and land slope. For example, “A, Grass, Flat” means SCS soil type A, native grass vegetative cover, and flat (0-1%) land slope.

There are four basic soil types: A (well infiltrating soils), B (moderate infiltrating soils), and C (poor infiltrating soils), and D (really poor infiltrating soils).

There are four basic land cover categories: grass, agricultural land, urban vegetation (lawns, flowers, planted shrubs), and trees.

Land slope is divided into flat (0-1%), moderate (1-2%), steep (2-5%), and very steep (>5%).

HSPF parameter values in SAHM have been adjusted for the different soil, land cover, and land slope categories based on the professional judgment and experience of Clear Creek Solutions HSPF modelers in northern California. SAHM HSPF soil parameter values take into account the hydrologic effects of land development activities that result from soil compaction.

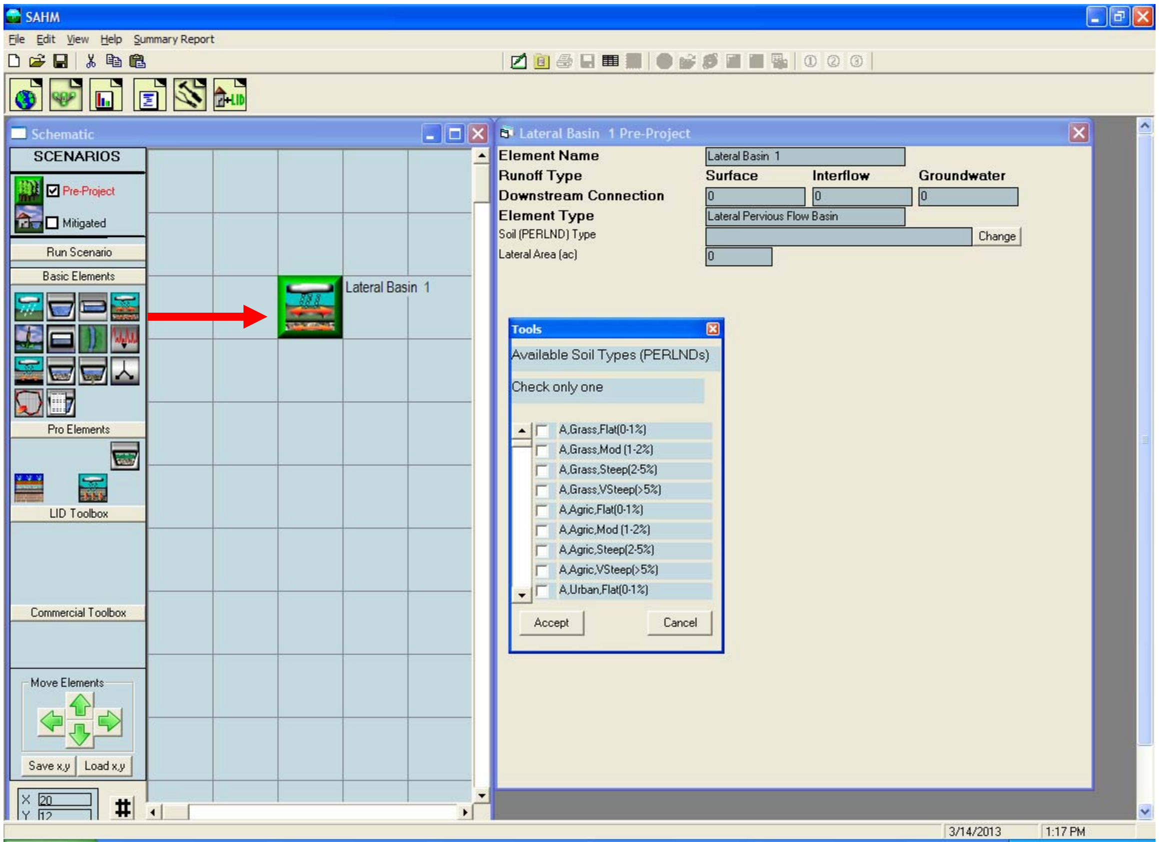
Impervious areas are divided into two different slopes (see Table 2). Impervious areas include roads, roofs, driveways, sidewalks, and parking. The slope categories are the same as for pervious areas (flat, moderate, steep, and very steep).

Table 2. SAHM Impervious Land Types

IMPLND No.	IMPLND Name	Land Slope
1	Impervious	Flat (0-1%)
2	Impervious	Moderate (1-2%)
3	Impervious	Steep (2-5%)
4	Impervious	Very Steep (>5%)

The user does not need to know or keep track of the HSPF IMPLND number. That number is used only for internal tracking purposes.

LATERAL BASIN ELEMENT (Pervious)



Runoff dispersion from impervious surfaces onto adjacent pervious land can be modeled using pervious and impervious lateral basins. For example, runoff from an impervious parking lot can sheet flow onto an adjacent lawn prior to draining into a stormwater conveyance system. This action slows the runoff and allows for some limited infiltration into the pervious lawn soil prior to discharging into a conveyance system.

The pervious lateral basin is similar to the standard basin except that the runoff from the lateral basin goes to another adjacent lateral basin (impervious or pervious) rather than directly to a conveyance system or stormwater facility. By definition, the pervious lateral basin contains only a single pervious land type. Impervious area is handled separately with the impervious lateral basin (Lateral I Basin).

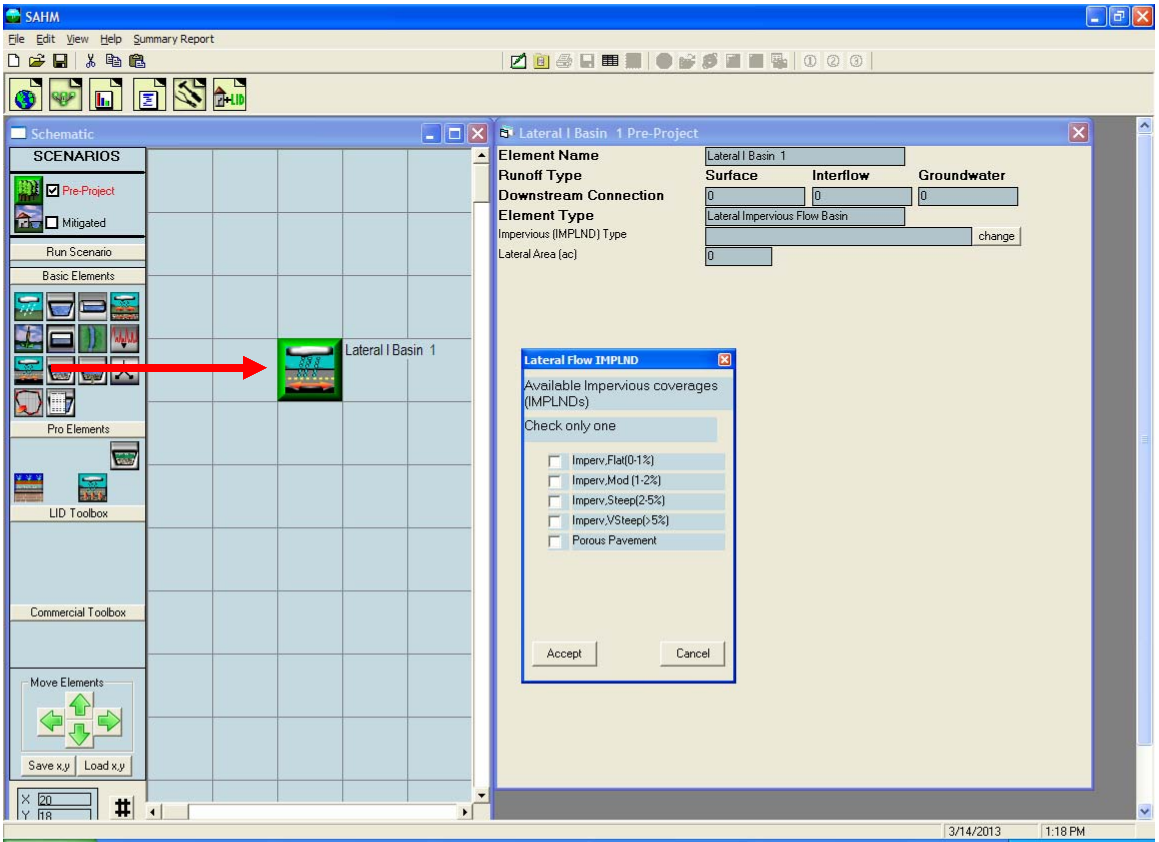
The user selects the pervious lateral basin land type by checking the appropriate box on the Available Soil Types Tools screen. This information is automatically placed in the Soil (PERLND) Type box above. Once entered, the land type can be changed by clicking on the Change button on the right.

The user enters the number of acres represented by the lateral basin land type.

If the lateral basin contains two or more pervious land use types then the user should create a separate lateral basin for each.

Note: The Sacramento Design Manual includes a restriction that the maximum allowable ratio of impervious lateral flow basin area to pervious (soil) flow basin area is 2 to 1.

LATERAL I BASIN ELEMENT (Impervious)



The impervious lateral basin is similar to the standard basin except that the surface runoff from the lateral impervious basin goes to another adjacent lateral basin (impervious or pervious) rather than directly to a conveyance system or stormwater facility. By definition, the impervious lateral basin contains only impervious land types. Pervious area is handled separately with the pervious lateral basin (Lateral Basin).

The user selects the impervious lateral basin land type by checking the appropriate box on the Available Impervious Coverages screen. This information is automatically placed in the Impervious (IMPLND) Type box above. Once entered, the land type can be changed by clicking on the Change button on the right.

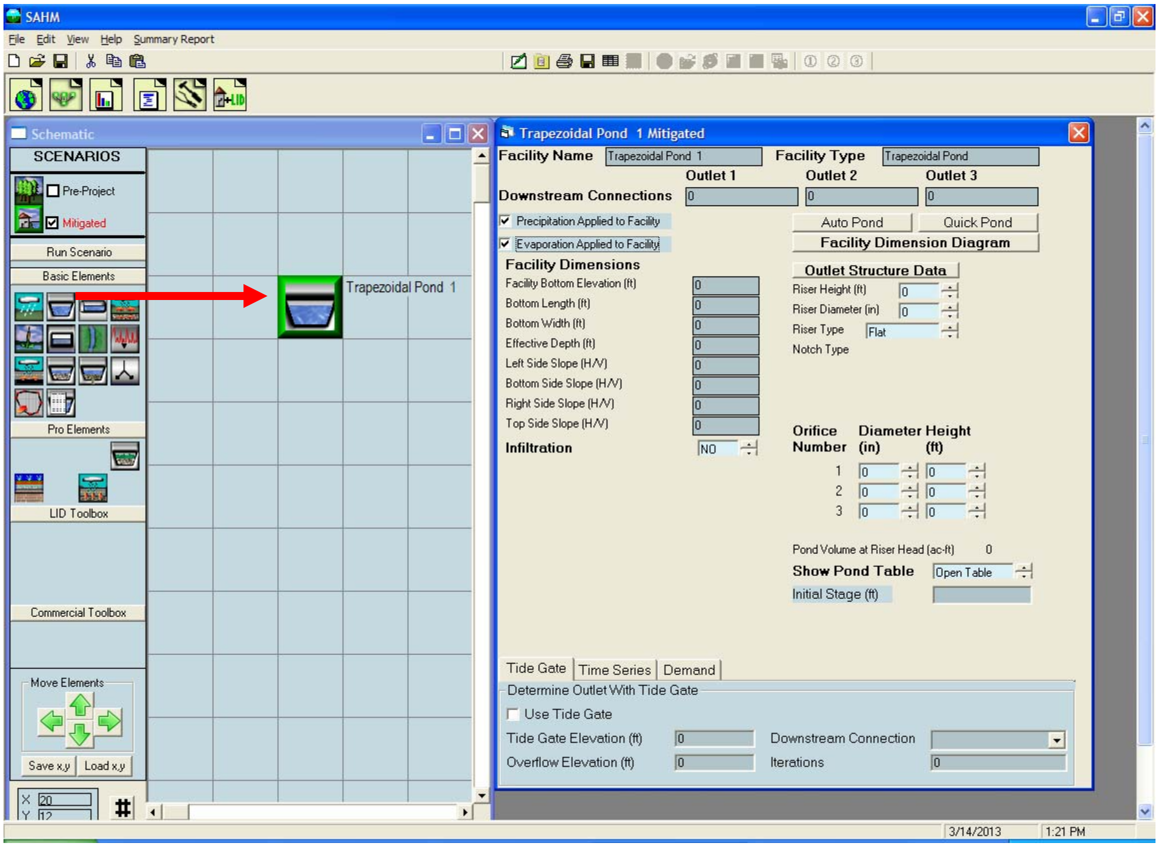
The user enters the number of acres represented by the lateral impervious basin land type.

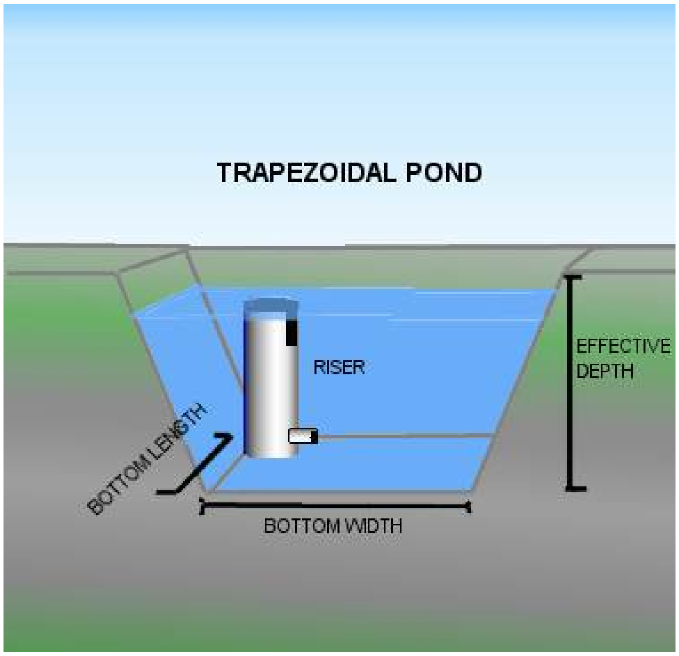
If the lateral impervious basin contains two or more impervious land use types then the user should create a separate lateral I basin for each.

To model parking lot runoff dispersion onto adjacent lawn connect the Lateral I Basin (the parking lot) to the Lateral Basin (the lawn). In the model's calculations surface runoff from the parking lot is added to the surface of the lawn (urban vegetation). The total runoff will then directed to a stormwater conveyance system by the user.

Note: The Sacramento Design Manual includes a restriction that the maximum allowable ratio of impervious lateral flow basin area to pervious (soil) flow basin area is 2 to 1.

TRAPEZOIDAL POND ELEMENT





In SAHM there is an individual pond element for each type of pond and stormwater control facility. The pond element shown above is for a trapezoidal pond. This is the most common type of stormwater pond.

A trapezoidal pond has dimensions (bottom length and width, depth, and side slopes) and an outlet structure consisting of a riser and one or more orifices to control the release of stormwater from the pond. A trapezoidal pond includes the option to infiltrate runoff, if the soils are appropriate and there is sufficient depth to the underlying groundwater table.

The user has the option to specify that different outlets be directed to different downstream destinations, although usually all of the outlets go to a single downstream location.

Auto Pond will automatically size a trapezoidal pond to meet the required flow duration criteria. Auto Pond is available only in the Mitigated scenario.

Quick Pond can be used to instantly add pond dimensions and an outlet configuration without checking the pond for compliancy with flow duration criteria. Quick Pond is sometimes used to quickly create a scenario and check the model linkages prior to sizing the pond. Multiple clicks on the Quick Pond button incrementally increase the pond size.

The user can change the default name "Trapezoidal Pond 1" to another more appropriate name, if desired.

Precipitation and evaporation must be applied to the pond unless the pond is covered.

The pond bottom elevation can be set to an elevation other than zero if the user wants to use actual elevations. All pond stage values are relative to the bottom elevation. Negative bottom elevations are not allowed.

The pond effective depth is the pond height (including freeboard) above the pond bottom. It is not the actual elevation of the top of the pond.

Pond side slopes are in terms of horizontal distance over vertical. A standard 3:1 (H/V) side slope would be given a value of 3. A vertical side slope has a value of 0.

The pond bottom is assumed to be flat.

The pond outlet structure consists of a riser and zero to three orifices. The riser has a height (typically one foot less than the effective depth) and a diameter. The riser can have either a flat top or a weir notch cut into the side of the top of the riser. The notch can be either rectangular, V-shaped, or a Sutro weir. More information on the riser weir shapes and orifices is provided later in this manual.

After the pond is given dimensions and outlet information the user can view the resulting stage-storage-discharge table by clicking on the "Open Table" arrow in the lower right corner of the pond information screen. This table hydraulically defines the pond's characteristics.

The user can use either Auto Pond to size a pond or can manually size a pond. Follow the following steps for manual sizing a pond using an outlet configuration with one orifice and a riser with rectangular notch (this is usually the most efficient design):

1. Input a bottom orifice diameter that allows a discharge equal to the lower threshold (e.g., 25% of 2-year) Pre-project flow for a stage equal to 2/3rds the

height of the riser. This discharge can be checked by reviewing the pond's stage-storage-discharge table.

2. Input a riser rectangular notch height equal to 1/3 of the height of the riser. Initially set the riser notch width to 0.1 feet.
3. Run Pre-project and Mitigated scenarios.
4. Go to Analysis screen and check flow duration results.
5. If pond passes flow duration criteria then decrease pond dimensions.
6. If pond fails flow duration criteria then change (in order of priority) bottom orifice diameter, riser notch width, pond dimensions.
7. Iterate until there is a good match between Pre-project and Mitigated flow duration curves or fatigue sets in.

Pond input information:
Bottom Length (ft): Pond bottom length.
Bottom Width (ft): Pond bottom width.
Effective Depth (ft): Pond height from pond bottom to top of riser plus at least 0.5 feet extra.
Left Side Slope (H/V): ratio of horizontal distance to vertical; 0 (zero) for vertical pond sides.
Bottom Side Slope (H/V): ratio of horizontal distance to vertical; 0 (zero) for vertical pond sides.
Right Side Slope (H/V): ratio of horizontal distance to vertical; 0 (zero) for vertical pond sides.
Top Side Slope (H/V): ratio of horizontal distance to vertical; 0 (zero) for vertical pond sides.
Riser Height (ft): Height of overflow pipe above pond bottom.
Riser Diameter (in): Pond overflow pipe diameter.
Riser Type (options): Flat or Notched
Notch Type: Rectangular, V-Notch, or Sutro.
For a rectangular notch:
Notch Height (feet): distance from the top of the weir to the bottom of the notch.
Notch Width (feet): width of notch; cannot be larger than the riser circumference.

For more information on riser notch options and orifices see discussion in OUTLET STRUCTURE CONFIGURATIONS section.

Infiltration: Yes (infiltration into the underlying native soil)
Measured Infiltration Rate (in/hr): Native soil infiltration rate.
Infiltration Reduction Factor: 1/Native soil infiltration rate safety factor (see page 74).
Use Wetted Surface Area (sidewalls): Yes, if infiltration through the pond side slopes is allowed.

If infiltration is used then the user should consult the Infiltration discussion on page 74.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.

A pond receives precipitation on and evaporation from the pond surface. The Precipitation Applied to Facility and Evaporation Applied to Facility boxes should be checked.

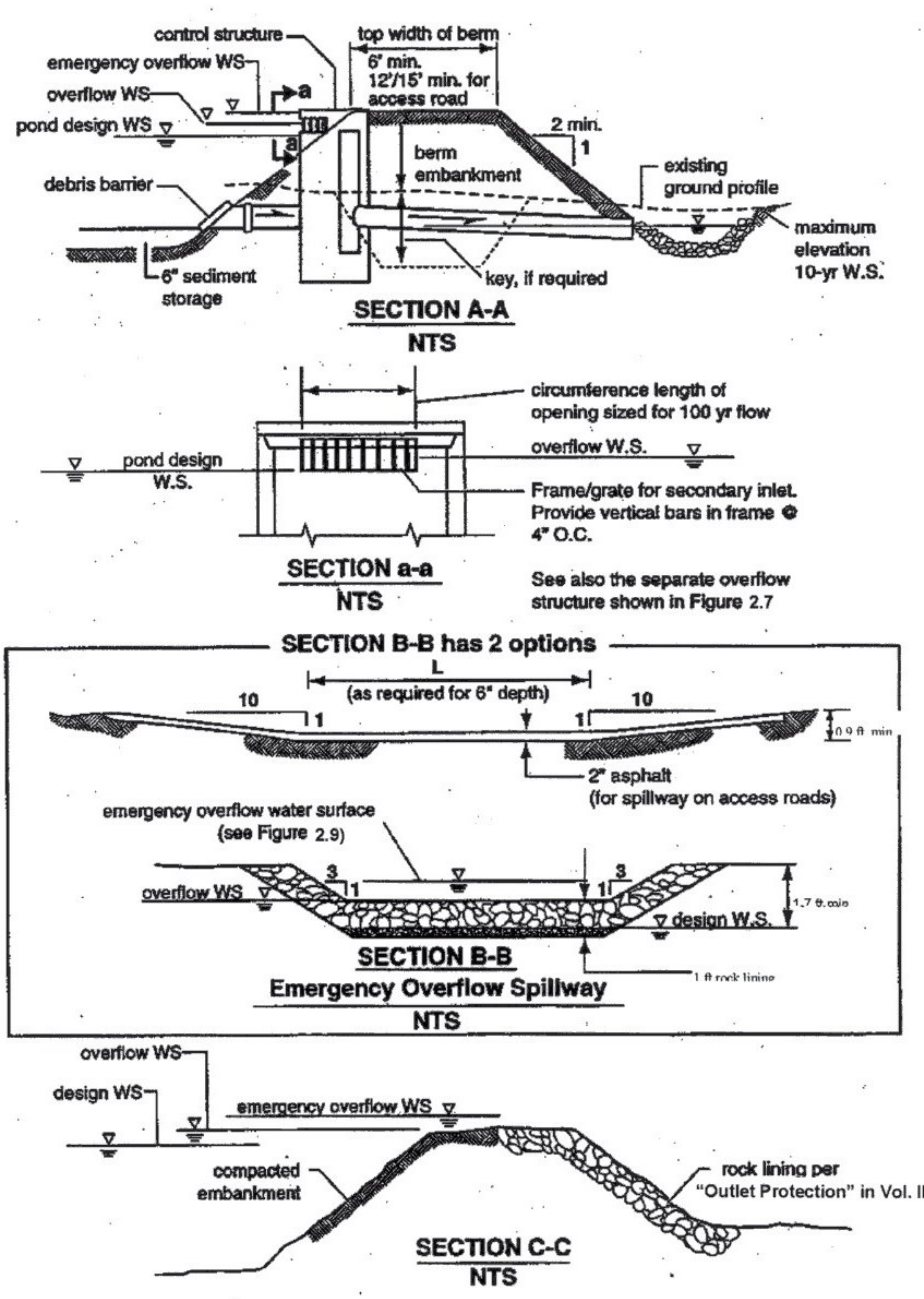
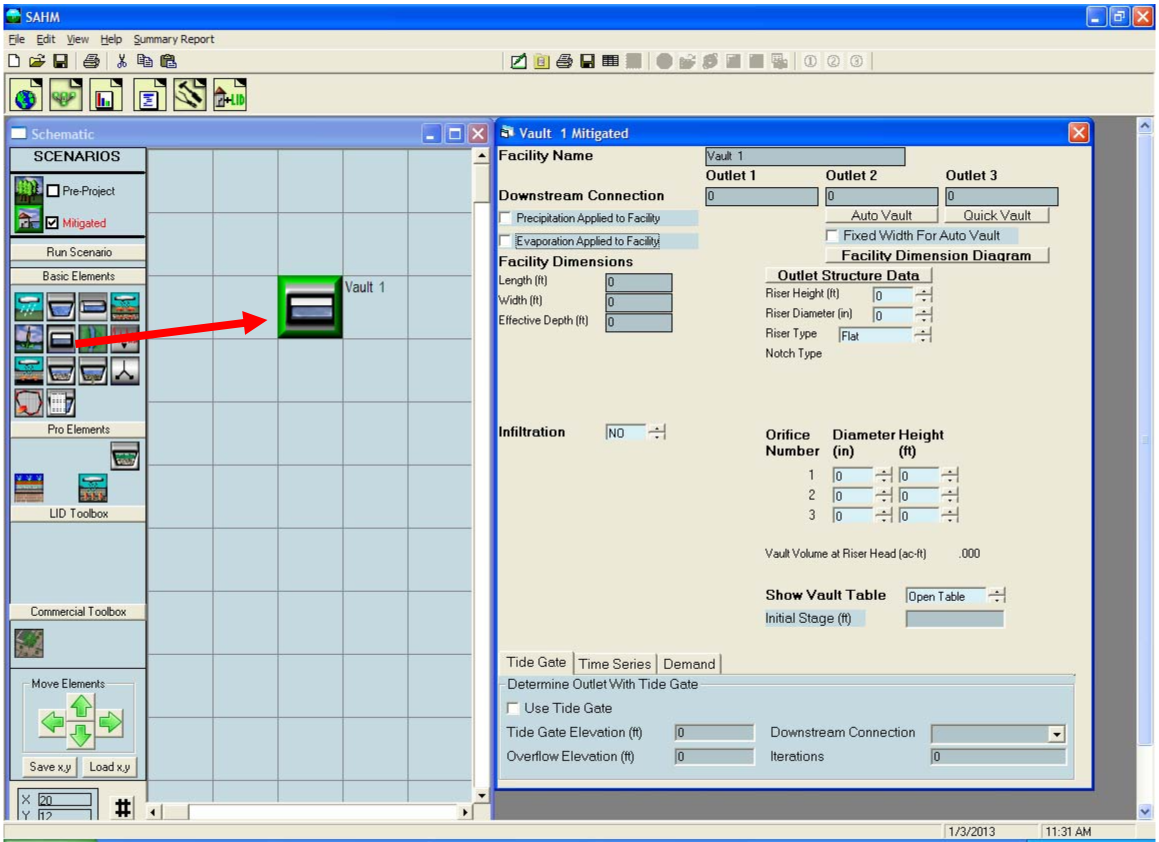


Figure 3.10 Typical Detention Pond Sections

NOTE: The detention pond section diagram shows the general configuration used in designing a pond and its outlet structure. This diagram is from the

Washington State Department of Ecology's 2005 Stormwater Management Manual for Western Washington. *Consult with your local municipal permitting agency on specific design requirements for your project site.*

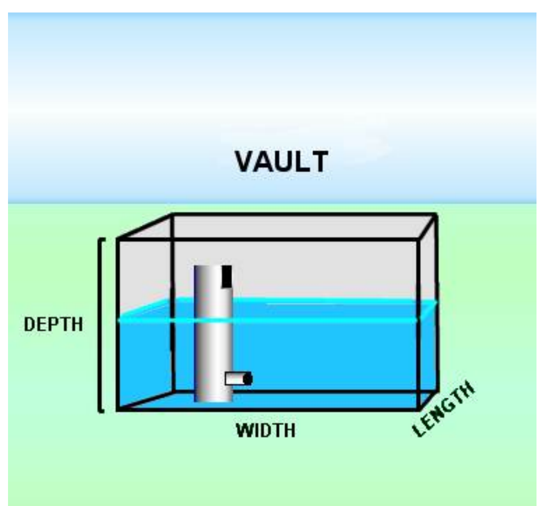
VAULT ELEMENT



The storage vault has all of the same characteristics of the trapezoidal pond, except that the user does not specify the side slopes (by definition they are zero) and the vault is assumed to have a lid (no precipitation or evaporation).

Auto Vault and Quick Vault work the same way as Auto Pond and Quick Pond. Go to page 52 to find information on how to manually size a vault or other HMP facility.

Vault input information:
Bottom Length (ft): Vault bottom length.
Bottom Width (ft): Vault bottom width.
Effective Depth (ft): Vault height from vault bottom to top of riser plus at least 0.5 feet extra.
Riser Height (ft): Height of overflow pipe above vault bottom.
Riser Diameter (in): Vault overflow pipe diameter.
Riser Type (options): Flat or Notched
Notch Type: Rectangular, V-Notch, or Sutro.



For a rectangular notch:
Notch Height (feet): distance from the top of the weir to the bottom of the notch.
Notch Width (feet): width of notch; cannot be larger than the riser circumference.

For more information on riser notch options and orifices see discussion in OUTLET STRUCTURE CONFIGURATIONS section.

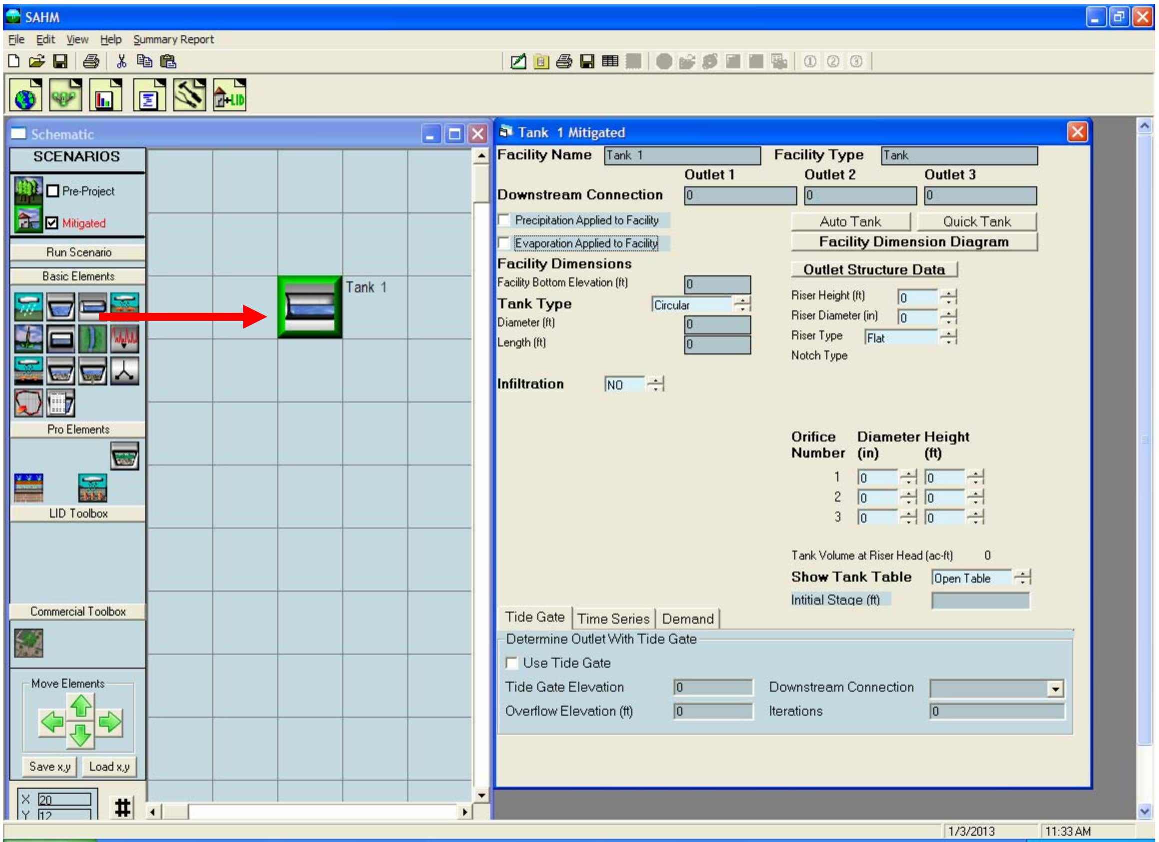
Infiltration: Yes (infiltration into the underlying native soil)
Measured Infiltration Rate (in/hr): Native soil infiltration rate.
Infiltration Reduction Factor: 1/Native soil infiltration rate safety factor (see page 74).
Use Wetted Surface Area (sidewalls): Yes, if infiltration through the vault sides is allowed.

If infiltration is used then the user should consult the Infiltration discussion on page 74.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.

A vault is usually covered and does not receive precipitation on and evaporation from the vault surface. The Precipitation Applied to Facility and Evaporation Applied to Facility boxes should not be checked unless the vault top is open to the atmosphere.

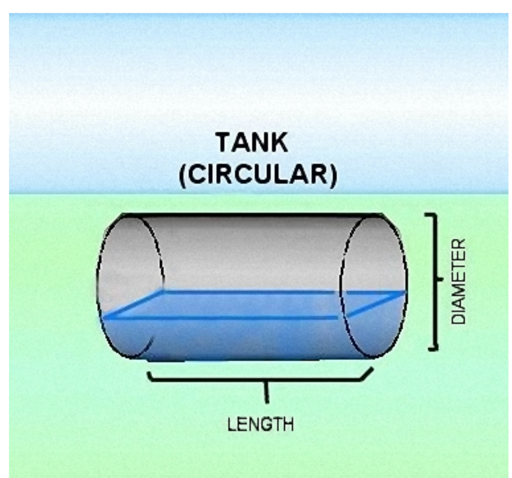
TANK ELEMENT



A storage tank is a cylinder placed on its side. The user specifies the tank's diameter and length.

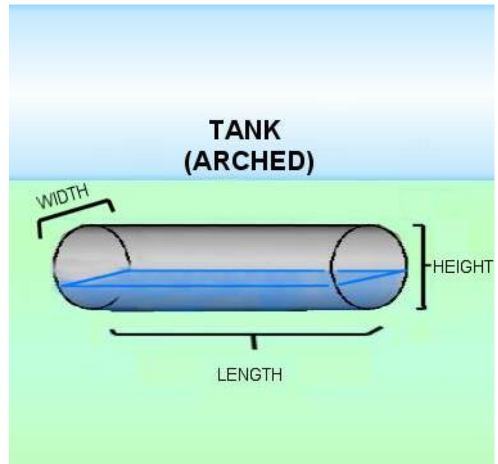
The tank element includes Auto Tank (automatic tank sizing routine). Or the user can manually size the tank to meet the flow duration criteria. Go to page 52 to find information on how to manually size a tank or other HMP facility.

There is a Quick Tank option that creates a tank, but does not check for compliance with the flow duration criteria.



Tank input information:
Tank Type: Circular or Arched
For Circular:
Diameter (ft): Tank diameter.
Length (ft): Tank length.
For Arched:
Height (ft): Tank height.

Width (ft): Tank width (at widest point).
Length (ft): Tank length.
Riser Height (ft): Height of overflow pipe above tank bottom; must be less than tank diameter or height.
Riser Diameter (in): Tank overflow pipe diameter.
Riser Type (options): Flat or Notched
Notch Type: Rectangular, V-Notch, or Sutro.
For a rectangular notch:
Notch Height (feet): distance from the top of the weir to the bottom of the notch.
Notch Width (feet): width of notch; cannot be larger than the riser circumference.



For more information on riser notch options and orifices see discussion in OUTLET STRUCTURE CONFIGURATIONS section.

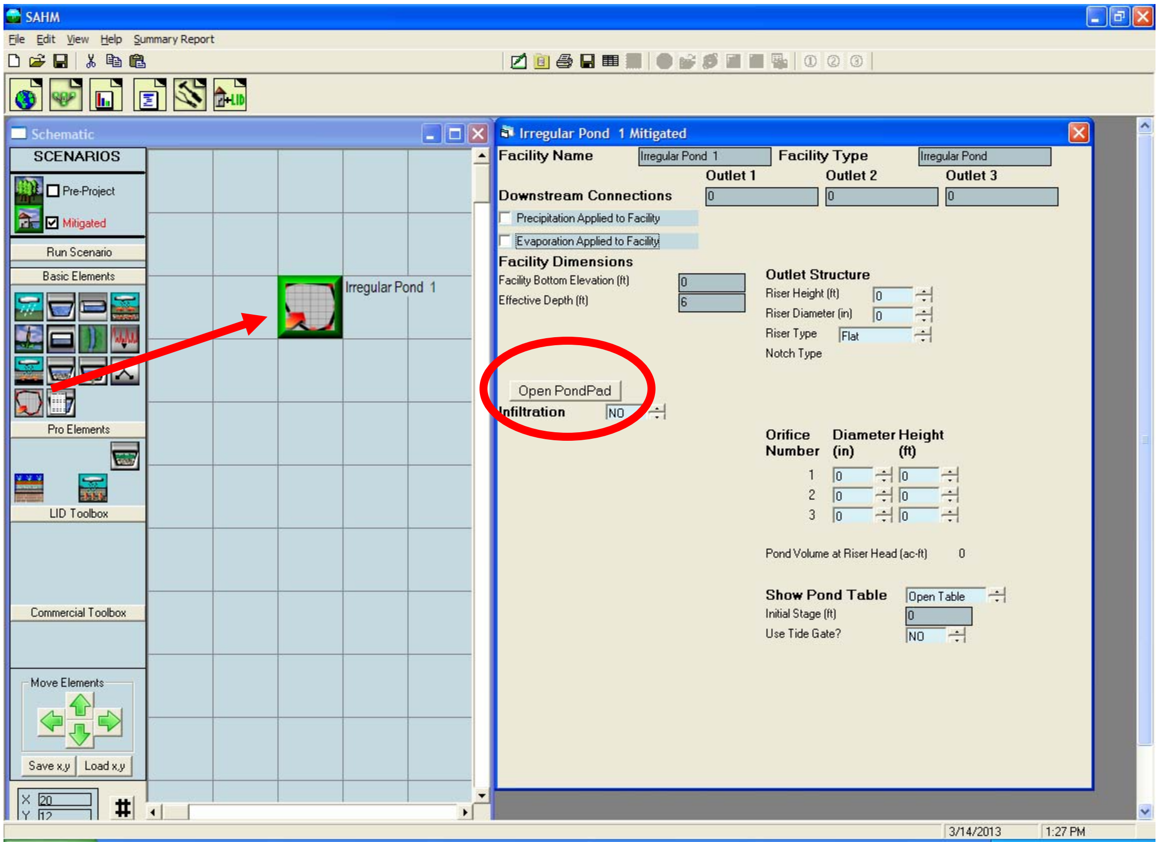
Infiltration: Yes (infiltration into the underlying native soil)
Measured Infiltration Rate (in/hr): Native soil infiltration rate.
Infiltration Reduction Factor: 1/Native soil infiltration rate safety factor (see page 74).
Use Wetted Surface Area (sidewalls): Yes, if infiltration through the tank sides is allowed.

If infiltration is used then the user should consult the Infiltration discussion on page 74.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.

A tank is covered and does not receive precipitation on and evaporation from the tank surface. The Precipitation Applied to Facility and Evaporation Applied to Facility boxes should not be checked.

IRREGULAR POND ELEMENT

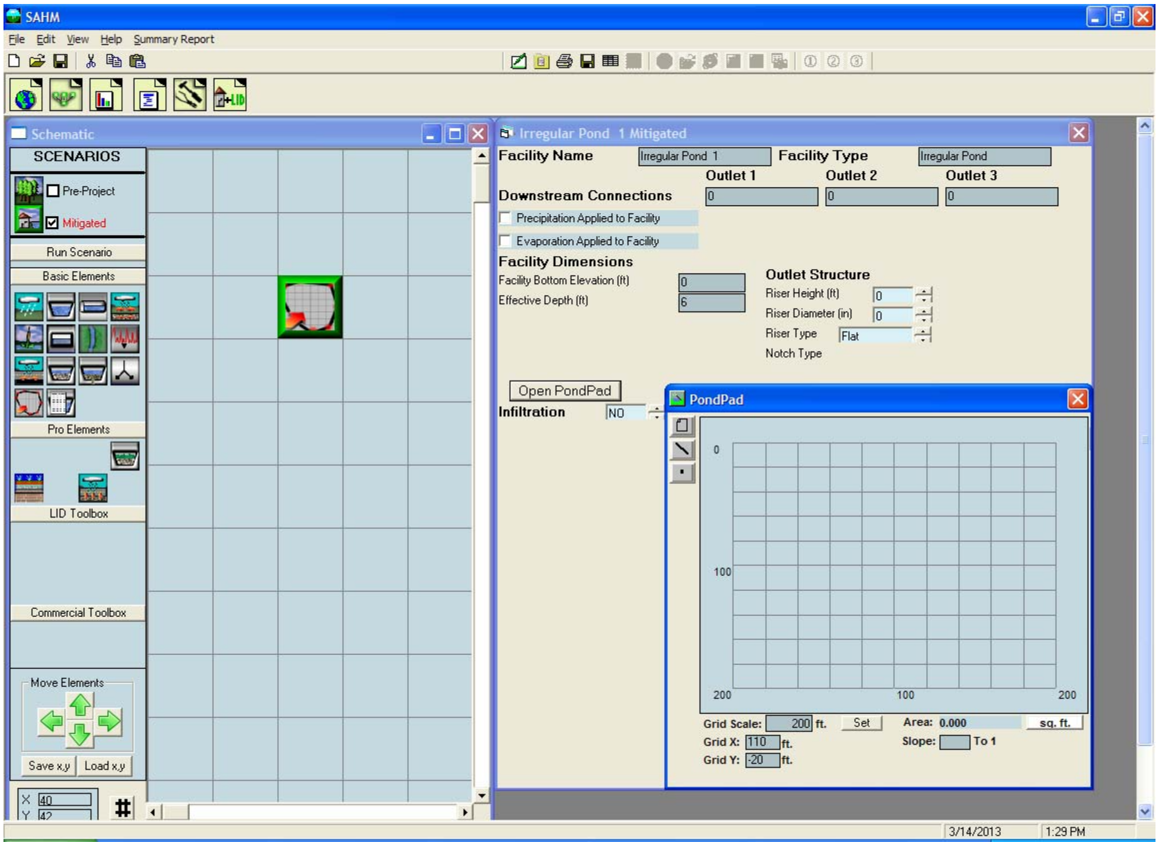


An irregular pond is any pond with a shape that differs from the rectangular top of a trapezoidal pond. An irregular pond has all of the same characteristics of a trapezoidal pond, but its shape must be defined by the user.

The Auto Pond option is not available for an irregular-shaped pond. Go to page 52 to find information on how to manually size an irregular pond or other HMP facility.

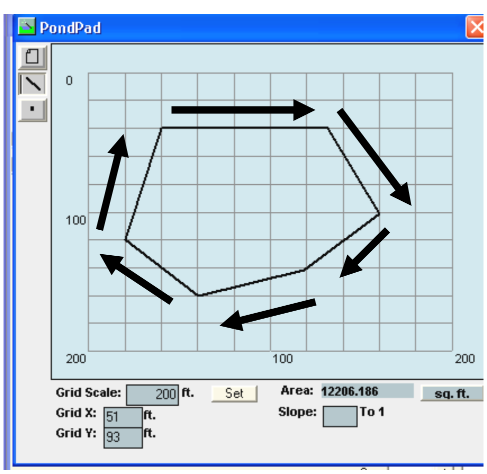
To create the shape of an irregular pond the user clicks on the “Open PondPad” button. This allows the user to access the PondPad interface (see below).

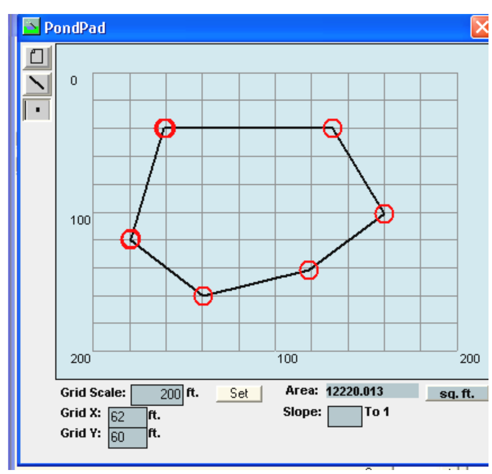
PondPad Interface



The PondPad interface is a grid on which the user can specify the outline of the top of the pond and the pond's side slopes.

The user selects the line button (second from the top on the upper left corner of the PondPad screen). Once the line button is turned on the user moves the mouse over the grid to locate the pond's corner points. The user does this in a **clockwise** direction to outline the pond's top perimeter. The user can select individual points by clicking on the point button immediately below the line button. Once selected, any individual point can be moved or repositioned.





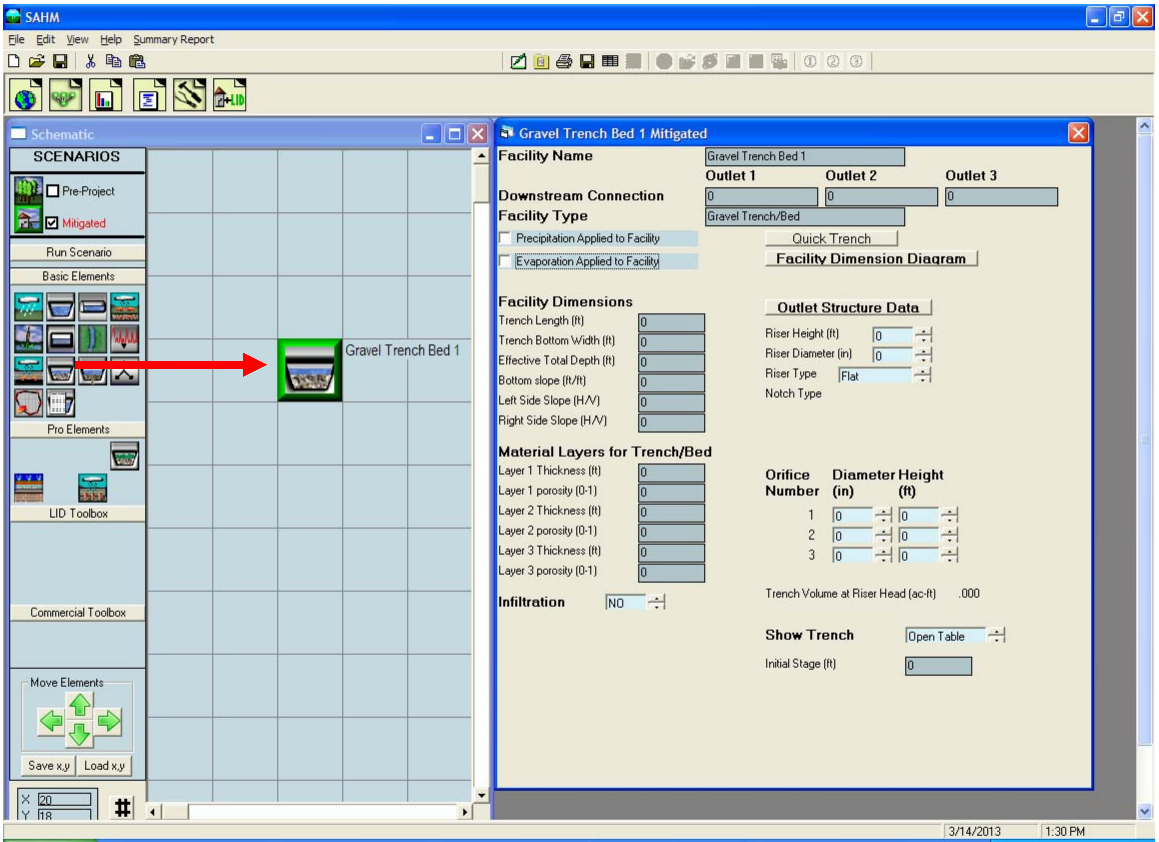
The default side slope value is 3 (3:1). The side slopes can be individually changed by right clicking on the specific side (which changes the line color from black to red) and then entering the individual side slope value in the slope text box.

The grid scale can be changed by entering a new value in the grid scale box. The default value is 200 feet.

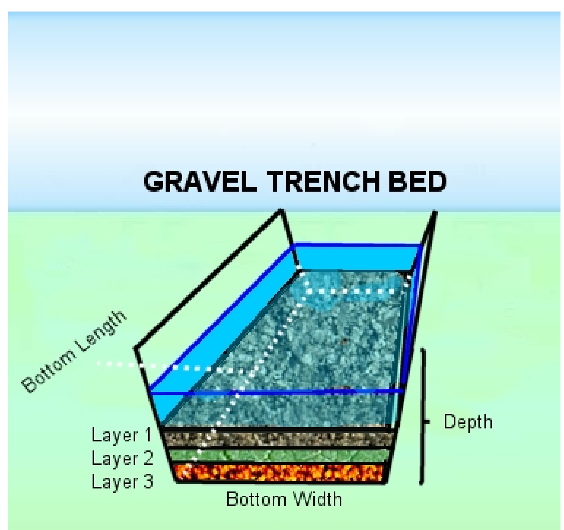
PondPad Controls and Numbers

Clear:	The Clear button clears all of the lines on the grid.
Line:	The Line button allows the user to draw new lines with the mouse.
Point:	The Point button allows the user to move individual points to alter the pond shape and size.
Sq Ft:	Converts the computed pond area from square feet to acres and back.
Grid Scale:	Changes the length of a grid line. Default grid scale is 200 feet.
Grid X:	Horizontal location of the mouse pointer on the grid (0 is the upper left corner).
Grid Y:	Vertical location of the mouse pointer on the grid (0 is the upper left corner)
Area:	Top area of the pond (either in square feet or acres).
Slope:	Side slope of the selected line (side of the pond).

GRAVEL TRENCH BED ELEMENT



The gravel trench bed is used to spread and infiltrate runoff, but also can have one or more surface outlets represented by an outlet structure with a riser and multiple orifices.



The user specifies the trench length, bottom width, total depth, bottom slope, and left and right side slopes.

The material layers represent the gravel/rock layers and their design characteristics (thickness and porosity).

Quick Trench will instantly create a gravel trench bed with default values without checking it for compliancy with flow duration criteria.

The gravel trench bed input information:

Trench Length (ft): Trench bed length.

Trench Bottom Width (ft): Trench bed bottom width.
Effective Total Depth (ft): Height from bottom of trench bed to top of riser plus at least 0.5 feet extra.
Bottom Slope of Trench (ft/ft): Must be non-zero.
Left Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical trench bed sides.

Right Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical trench bed sides.
Infiltration Rate (in/hr): Trench bed gravel or other media infiltration rate.
Layer 1 Thickness (ft): Trench top media layer depth.
Layer 1 Porosity: Trench top media porosity.
Layer 2 Thickness (ft): Trench middle media layer depth (Layer 2 is optional).
Layer 2 Porosity: Trench middle media porosity.
Layer 3 Thickness (ft): Trench bottom media layer depth (Layer 3 is optional).
Layer 3 Porosity: Trench bottom media porosity.
Riser Height (ft): Height of trench overflow pipe above trench surface.
Riser Diameter (in): Trench overflow pipe diameter.
Riser Type (options): Flat or Notched
Notch Type: Rectangular, V-Notch, or Sutro.
For a rectangular notch:
Notch Height (feet): distance from the top of the weir to the bottom of the notch.
Notch Width (feet): width of notch; cannot be larger than the riser circumference.

For more information on riser notch options and orifices see discussion in OUTLET STRUCTURE CONFIGURATIONS section.

Native Infiltration: Yes (infiltration into the underlying native soil)
Measured Infiltration Rate (in/hr): Native soil infiltration rate.
Infiltration Reduction Factor: 1/Native soil infiltration rate safety factor (see page 74).
Use Wetted Surface Area (sidewalls): Yes, if infiltration through the trench side slopes is allowed.

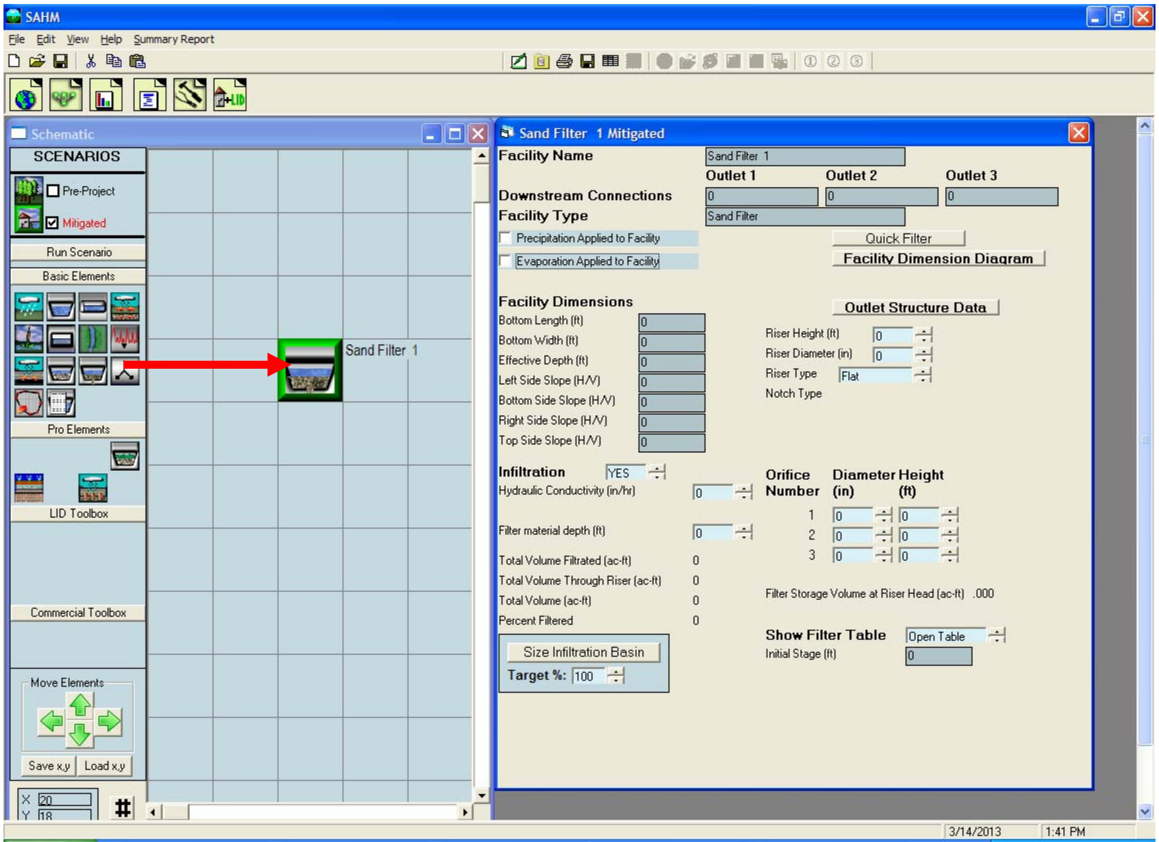
If infiltration is used then the user should consult the Infiltration discussion on page 74.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.

Gravel trench bed receives precipitation on and evaporation from the trench surface. The Precipitation Applied to Facility and Evaporation Applied to Facility boxes should be checked.

Note: a gravel trench bed is assumed to fill with stormwater from the bottom of the trench to the top. By comparison, a bioretention facility fills from the surface down to the bottom.

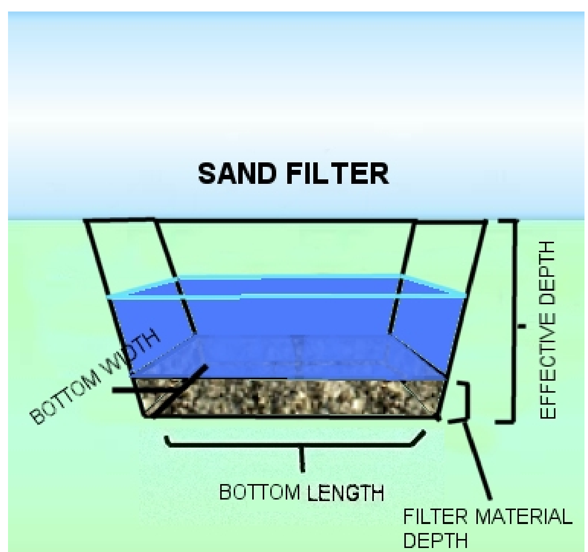
SAND FILTER ELEMENT



The sand filter is a water quality facility. It does not infiltrate runoff, but is used to filter runoff through a medium and send it downstream. It can also have one or more surface outlets represented by an outlet structure with a riser and multiple orifices.

The user must specify the facility dimensions (bottom length and width, effective depth, and side slopes. The hydraulic conductivity of the sand filter and the filter material depth are also needed to size the sand filter (default values are 1.0 inch per hour and 1.5 feet, respectively).

NOTE: When using the sand filter element check with Appendix C or the local municipal permitting agency to determine the required treatment standard (percent of the total runoff volume treated by the sand filter).



The filter discharge is calculated using the equation Q = K*I*A, where Q is the discharge in cubic feet per second (cfs). K equals the hydraulic conductivity (inches per hour). For sand filters K = 1.0 in/hr. Sand is the default medium. If another filtration material is used then the design engineer should enter the appropriate K value supported by documentation and approval by the reviewing authority.

Design of a sand filter requires input of facility dimensions and outlet structure characteristics, running the sand filter scenario, and then checking the volume calculations to see if the Percent Filtered equals or exceeds the treatment standard percentage. If the value is less than the treatment standard percentage then the user should increase the size of the sand filter dimensions and/or change the outlet structure. The sand filter input information:

Bottom Length (ft): Sand filter bottom length.
Bottom Width (ft): Sand filter bottom width.
Effective Depth (ft): Height from bottom of sand filter to top of riser plus at least 0.5 feet extra.
Left Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical sand filter sides.
Bottom Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical sand filter sides.
Right Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical sand filter sides.
Top Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical sand filter sides.

Riser Height (ft): Height of sand filter overflow pipe above sand filter surface.
Riser Diameter (in): Sand filter overflow pipe diameter.
Riser Type (options): Flat or Notched
Notch Type: Rectangular, V-Notch, or Sutro.
For a rectangular notch:
Notch Height (feet): distance from the top of the weir to the bottom of the notch.
Notch Width (feet): width of notch; cannot be larger than the riser circumference.

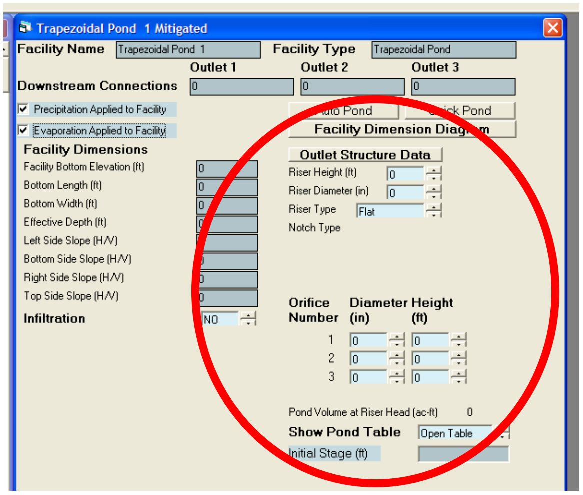
For more information on riser notch options and orifices see discussion in OUTLET STRUCTURE CONFIGURATIONS section.

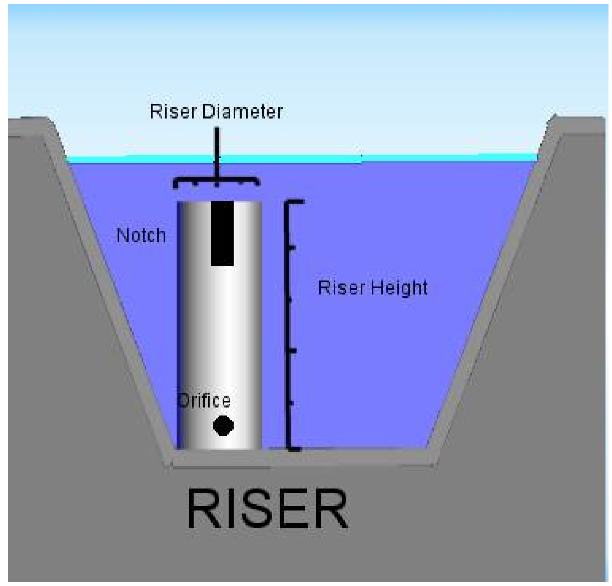
Infiltration: Yes (infiltration through the filter material)
Hydraulic Conductivity (in/hr): Filtration rate through the sand filter.
Filter material depth (ft): Depth of sand filter material (for runoff filtration).

Sand filter receives precipitation on and evaporation from the sand filter surface. The Precipitation Applied to Facility and Evaporation Applied to Facility boxes should be checked.

OUTLET STRUCTURE CONFIGURATIONS

The trapezoidal pond, vault, tank, irregular pond, gravel trench bed, and sand filter all use a riser for the outlet structure to control discharge from the facility.

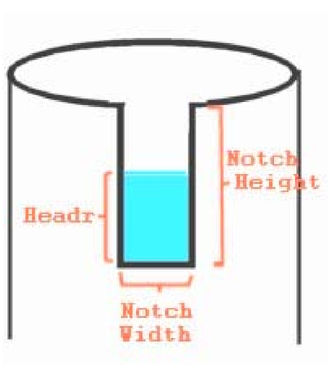




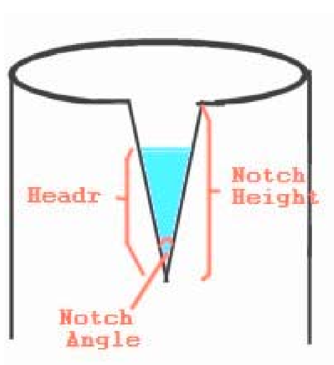
The riser is a vertical pipe with a height above pond bottom (typically one foot less than the effective depth). The user specifies the riser height and diameter.

The riser can have up to three round orifices. The bottom orifice is usually located at the bottom of the pond and/or above any dead storage in the facility. The user can set the diameter and height of each orifice.

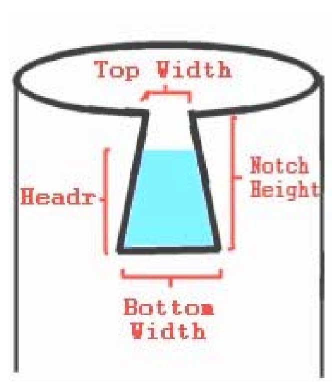
The user specifies the riser type as either flat or notched. The weir notch can be either rectangular, V-notch, or a Sutro weir. The shape of each type of weir is shown below.



Rectangular Notch



V-Notch



Sutro

By selecting the appropriate notch type the user is then given the option to enter the appropriate notch type dimensions.

Riser and orifice equations used in SAHM are provided below.

Headr = the water height over the notch/orifice bottom.
q = discharge

Riser Head Discharge:

Head = water level above riser
q = 9.739 * Riser Diameter * Head ^ 1.5

Orifice Equation:
q = 3.782 * (Orifice Diameter) ^ 2 * SQRT(Headr)

Rectangular Notch:
b = NotchWidth *- (1- 0.2 * Headr)
where b >= 0.8
q = 3.33 * b * Headr ^ 1.5

Sutro:
Wh = Top Width + {(Bottom Width- Top Width)/Notch Height }* Headr
Wd = Bottom Width - Wh (the difference between the bottom and top widths)

Q1 = (rectangular notch q where Notch Width = Wh)
Q2 = (rectangular notch q where Notch Width = Wd)

q = Q1 + Q2 / 2

V-Notch:
Notch Bottom = height from bottom of riser to bottom of notch
Theta = Notch Angle

a = 2.664261 - 0.0018641 * Theta + 0.00005761 * Theta ^2
b = -0.48875 + 0.003843 * Theta - 0.000092124 * Theta ^2
c = 0.3392 - 0.0024318 * Theta + 0.00004715 * Theta ^2

YoverH = Headr / (NotchBottom + Headr)
Coef = a + b * Headr + c * Headr ^2

q = (Coef * Tan(Theta / 2)) * (Headr ^ (5 / 2))

These equations are provided from the Washington State Department of Ecology’s 2005 *Stormwater Management Manual for Western Washington.* The outlet designs are shown

below. They have been reproduced from Volume III of the *Stormwater Management Manual for Western Washington* which has more information on the subject.

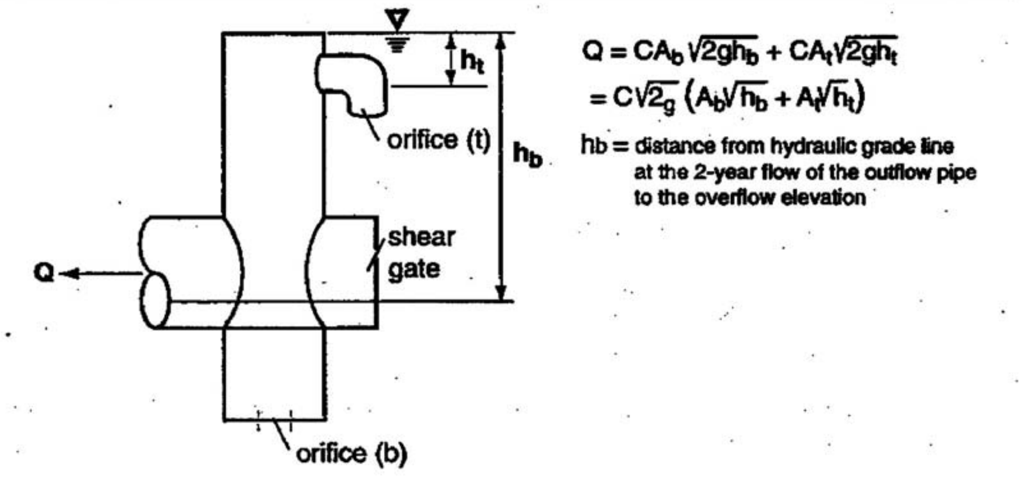


Figure 3.20 Simple Orifice

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(equation 5)}$$

where d = orifice diameter (inches)
Q = flow (cfs)
h = hydraulic head (ft)

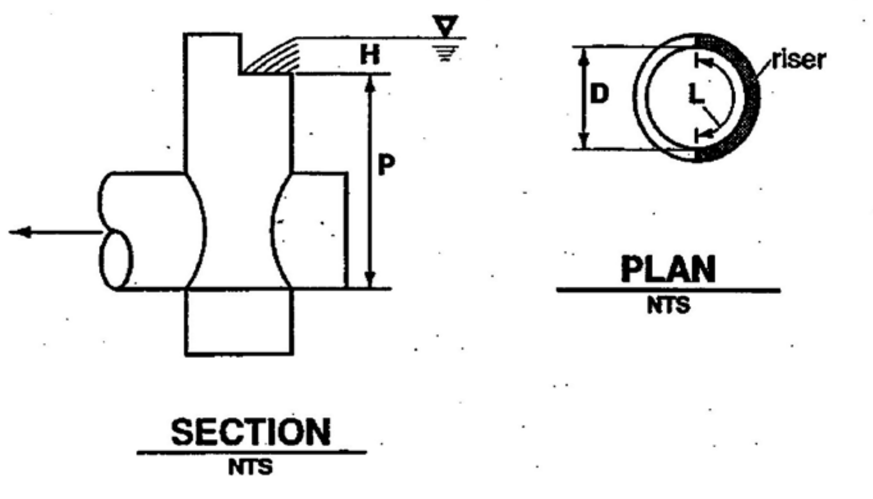


Figure 3.21 Rectangular, Sharp-Crested Weir

$Q = C (L - 0.2H) H^{3/2}$ (equation 6)

where Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P are as shown above
L = length (ft) of the portion of the riser circumference as necessary not to exceed 50 percent of the circumference
D = inside riser diameter (ft)

Note that this equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.

The physical configuration of the outlet structure should include protection for the riser and orifices to prevent clogging of the outlet from debris or sediment. Various outlet configurations are shown below. They have been reproduced from Volume III of the *Stormwater Management Manual for Western Washington* which has more information on the subject.

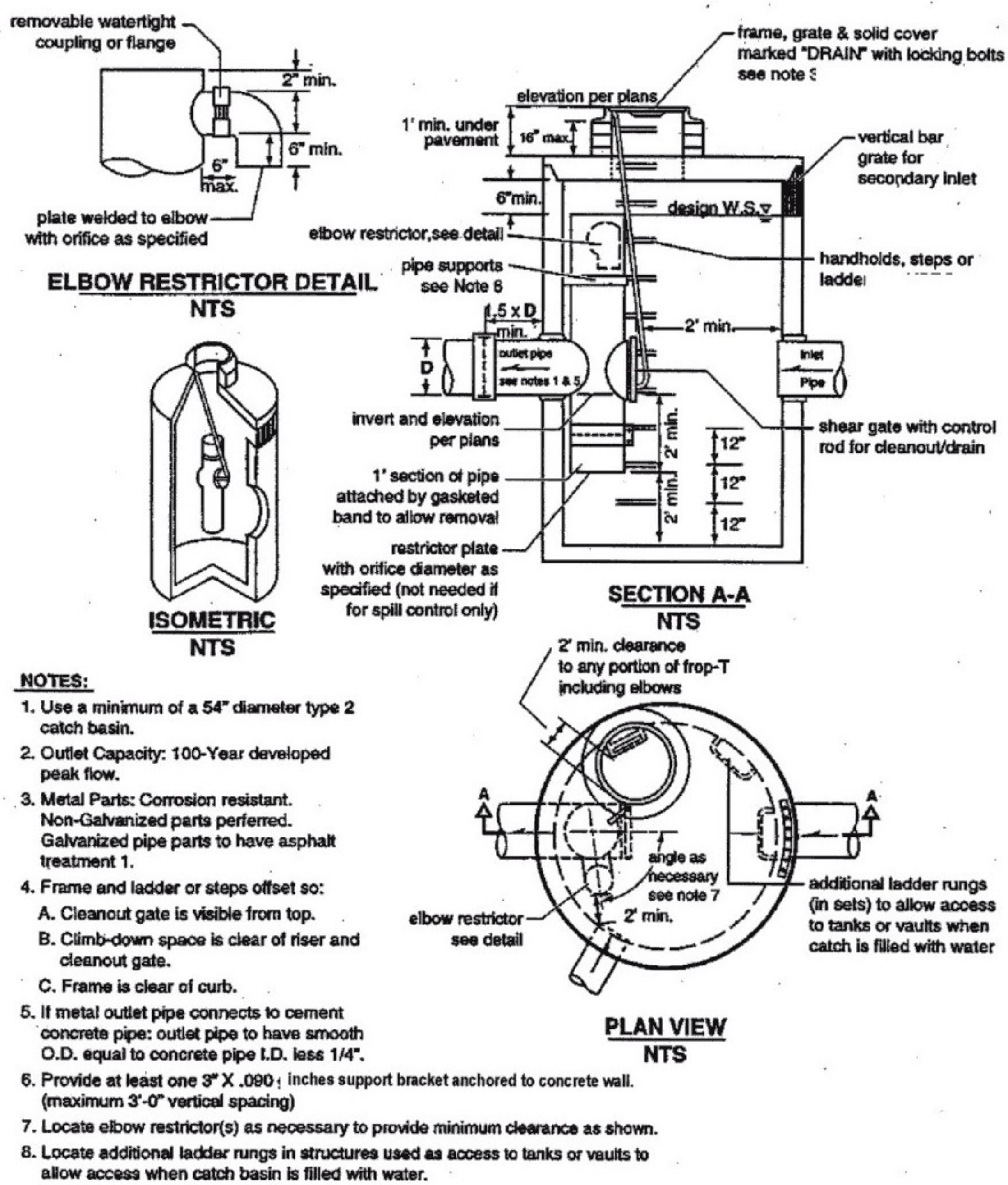


Figure 3.17 Flow Restrictor (TEE)

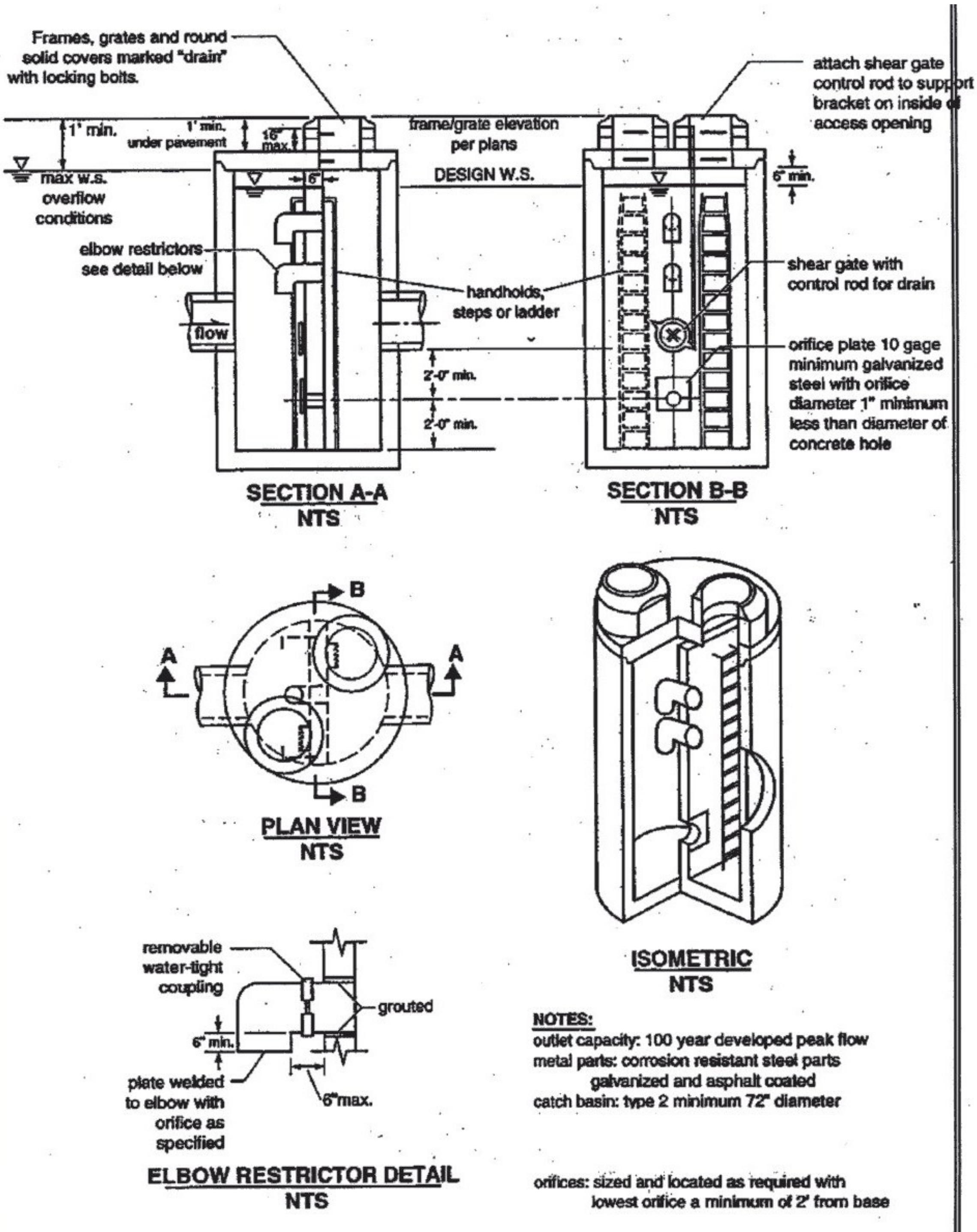


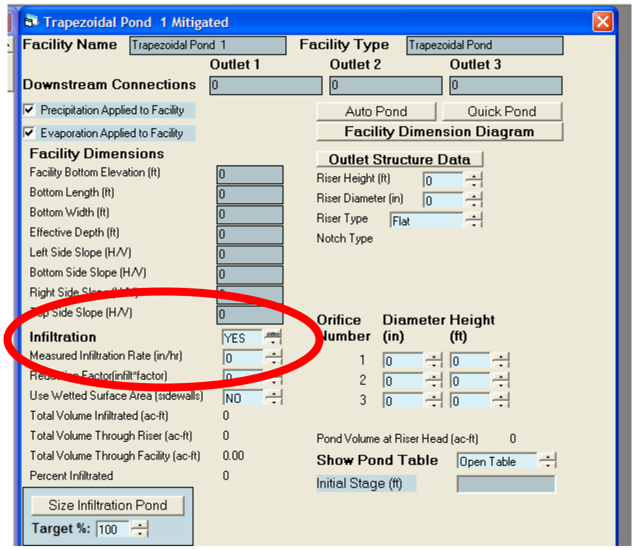
Figure 3.18 Flow Restrictor (Baffle)

Riser protection structures. Diagrams courtesy of Washington State Department of Ecology.

INFILTRATION

Infiltration of stormwater runoff is a recommended solution if certain conditions are met. These conditions include: a soils report, testing, groundwater protection, pre-settling, and appropriate construction techniques.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.



The user clicks on the Infiltration option arrow to change infiltration from NO to YES. This activates the infiltration input options: measured infiltration rate, infiltration reduction factor, and whether or not to allow infiltration through the wetted side slopes/walls.

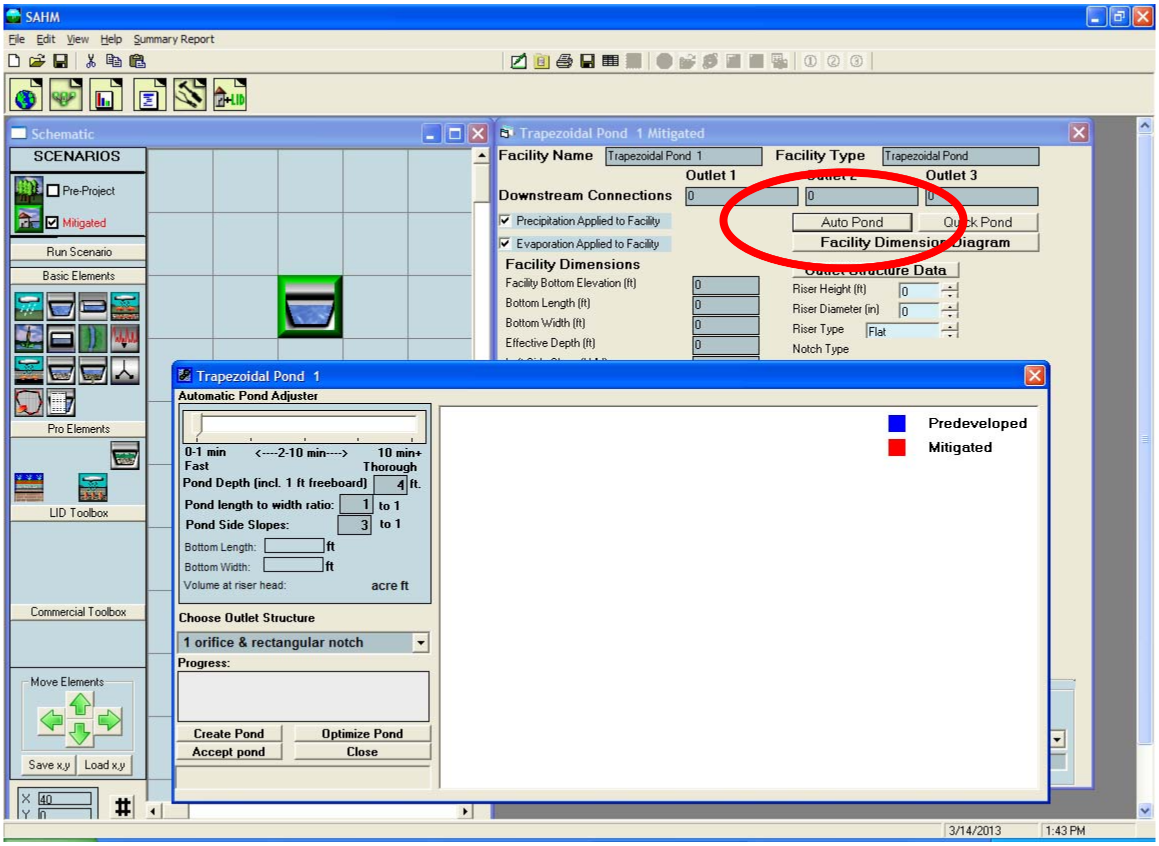
The infiltration reduction factor is a multiplier for the measured infiltration rate and should be less than one. It is the same as the inverse of a safety factor. For example, a safety factor of 2 is equal to a reduction factor of 0.5.

Infiltration occurs only through the bottom of the facility if the wetted surface area option is turned off. Otherwise the entire wetted surface area is used for infiltration.

After the model is run and flow is routed through the infiltration facility the total volume infiltrated, total volume through the riser, total volume through the facility, and percent infiltrated are reported on the screen. If the percent infiltrated is 100% then there is no surface discharge from the facility. The percent infiltrated can be less than 100% as long as the surface discharge does not exceed the flow duration criteria.

The user can set an infiltration target (100% or less) and SAHM will iterate to size the facility to meet that target infiltration total.

AUTO POND



Auto Pond automatically creates a pond size and designs the outlet structure to meet the flow duration criteria. The user can either create a pond from scratch or optimize an existing pond design.

Auto Pond requires that the Pre-project and Mitigated basins be defined prior to using Auto Pond. Clicking on the Auto Pond button brings up the Auto Pond window and the associated Auto Pond controls.

Auto Pond controls:

Automatic Pond Adjuster: The slider at the top of the Auto Pond window allows the user to decide how thoroughly the pond will be designed for efficiency. The lowest setting (0-1 min) at the left constructs an initial pond without checking the flow duration criteria. The second setting to the right creates and sizes a pond to pass the flow duration criteria; however, the pond is not necessarily optimized. The higher settings increase the amount of optimization. The highest setting (farthest right) will size the most efficient (smallest) pond, but will result in longer computational time.

Pond Depth: Pond depth is the total depth of the pond and should include at least one foot of freeboard (above the riser). The pond's original depth will be used when optimizing an existing pond; changing the value in the Pond Depth text box will override any previous set depth value. The default depth is 4 feet.

Pond Length to Width Ratio: This bottom length to width ratio will be maintained regardless of the pond size or orientation. The default ratio value is 1.0

Pond Side Slopes: Auto Pond assumes that all of the pond's sides have the same side slope. The side slope is defined as the horizontal distance divided by the vertical. A typical side slope is 3 (3 feet horizontal to every 1 foot vertical). The default side slope value is 3.

Choose Outlet Structure: The user has the choice of either 1 orifice and rectangular notch or 3 orifices. If the user wants to select another outlet structure option then the pond must be manually sized.

Create Pond: This button creates a pond when the user does not input any pond dimensions or outlet structure information. Any previously input pond information will be deleted.

Optimize Pond: This button optimizes an existing pond. It cannot be used if the user has not already created a pond.

Accept Pond: This button will stop the Auto Pond routine at the last pond size and discharge characteristics that produce a pond that passes the flow duration criteria. Auto Pond will not stop immediately if the flow duration criteria have not yet been met.

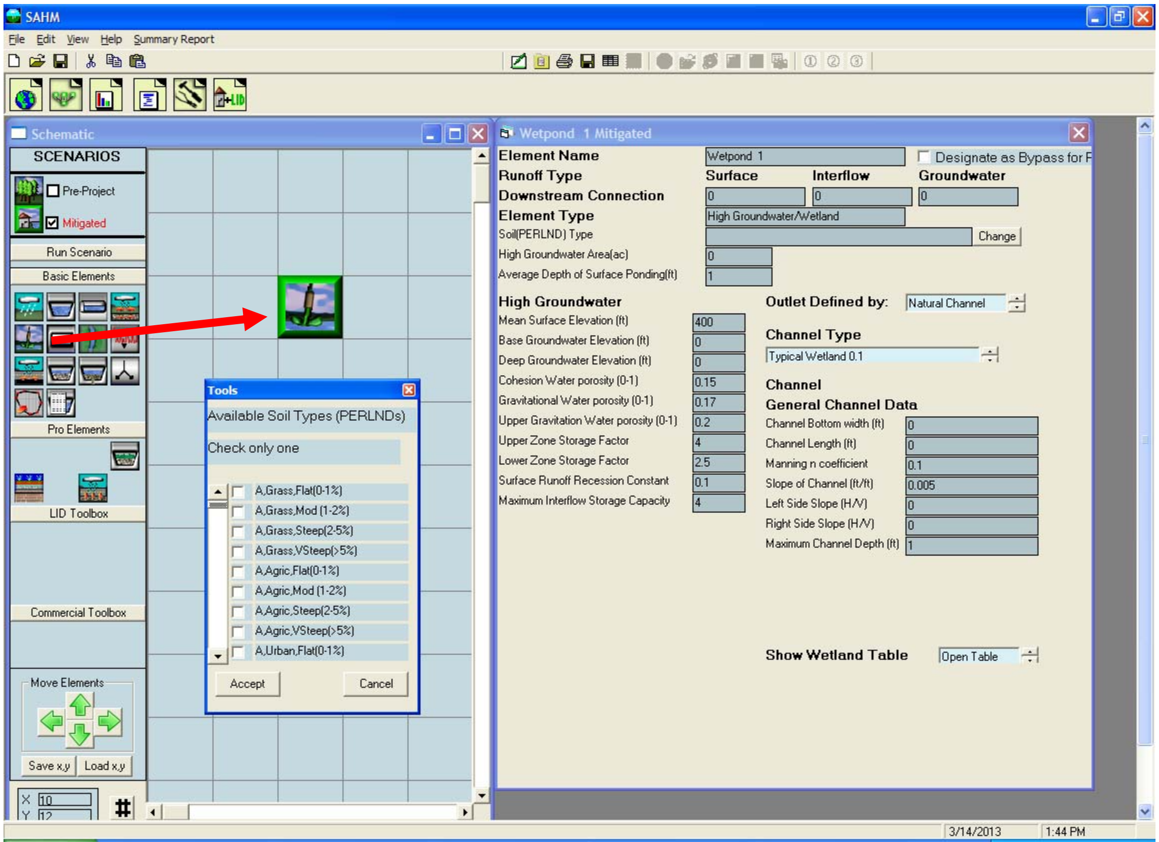
The bottom length and width and volume at riser head will be computed by Auto Pond; they cannot be input by the user.

Auto Vault operates the same way as Auto Pond.

There are some situations where Auto Pond (or Auto Vault) will not work. These situations occur when complex routing conditions upstream of the pond make it difficult or impossible for Auto Pond to determine which land use will be contributing runoff to the pond. For these situations the pond will have to be manually sized. Go to page 52 to find information on how to manually size a pond or other HMP facility.

NOTE: If Auto Pond selects a bottom orifice diameter smaller than the smallest diameter allowed by the local municipal permitting agency then additional mitigating BMPs may be required to meet local hydromodification control requirements. Please see Appendix C or consult with local municipal permitting agency for more details. For manual sizing information see page 52.

HIGH GROUNDWATER/WETLAND ELEMENT



The High Groundwater/Wetpond element is a complex element that should only be used in special applications by advanced SAHM users. The purpose of the high groundwater/wetpond element is to model hydrologic conditions where high groundwater rises to the surface (or near the surface) and reduces the ability of water to infiltrate into the soil.

The element can be used to represent wetland conditions with surface ponding where the discharge from the wetland is via a surface release. The user is given the choice of using either a natural channel, berm/weir, or control structure to determine the release characteristics.

The element provides default values for some of the parameters, especially as they relate to high groundwater. The user should be fully familiar with these parameters and the appropriate values for their site prior to attempting to use this element. The high groundwater parameter definitions are shown below.

Cohension water porosity: soil pore space in micropores.

Gravitational water porosity: soil pore space in macropores in the lower and groundwater layers of the soil column.

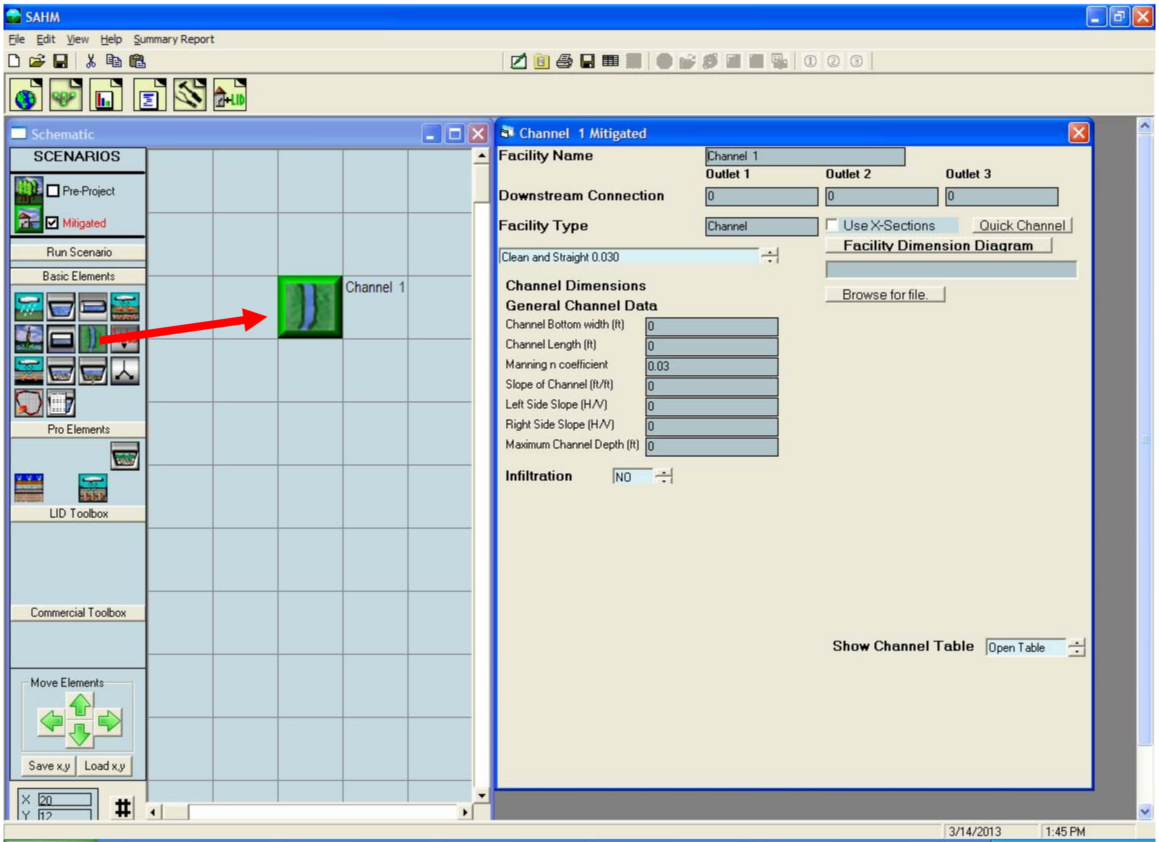
Upper gravitation water porosity: soil pore space in macropores in the upper layer of the soil column.

Upper zone storage factor: portion of the water stored in macropores in the upper soil layer which will not surface discharge, but will percolate, evaporate or transpire.

Lower zone storage factor: portion of the water stored in micropores in the lower soil layer which will not gravity drain, but will evaporate or transpire.

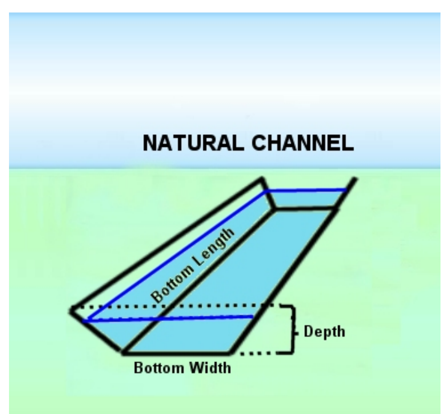
NOTE: Due to permit restrictions on infiltration for stormwater treatment measures in areas of high groundwater, consult with the local municipal permitting agency regarding any project conditions that might involve using this element.

CHANNEL ELEMENT



The Channel element allows the user to route runoff from a basin or facility through an open channel to a downstream destination.

The channel cross section is represented by a trapezoid and is used with Manning's equation to calculate discharge from the channel. If a trapezoid does not accurately represent the cross section then the user should represent the channel with an independently calculated SSD Table element or use the Use X-Sections option.



The user inputs channel bottom width, channel length, channel bottom slope, channel left and right side slopes, maximum channel depth, and the channel's roughness coefficient (Manning's n value). The user can select channel type and associated Manning's n from a table list directly above the Channel Dimension information or directly input the channel's Manning's n value.

The channel is used to represent a natural or artificial open channel through which water is routed. It can

be used to connect a basin to a pond or a pond to a pond or multiple channels can linked together.

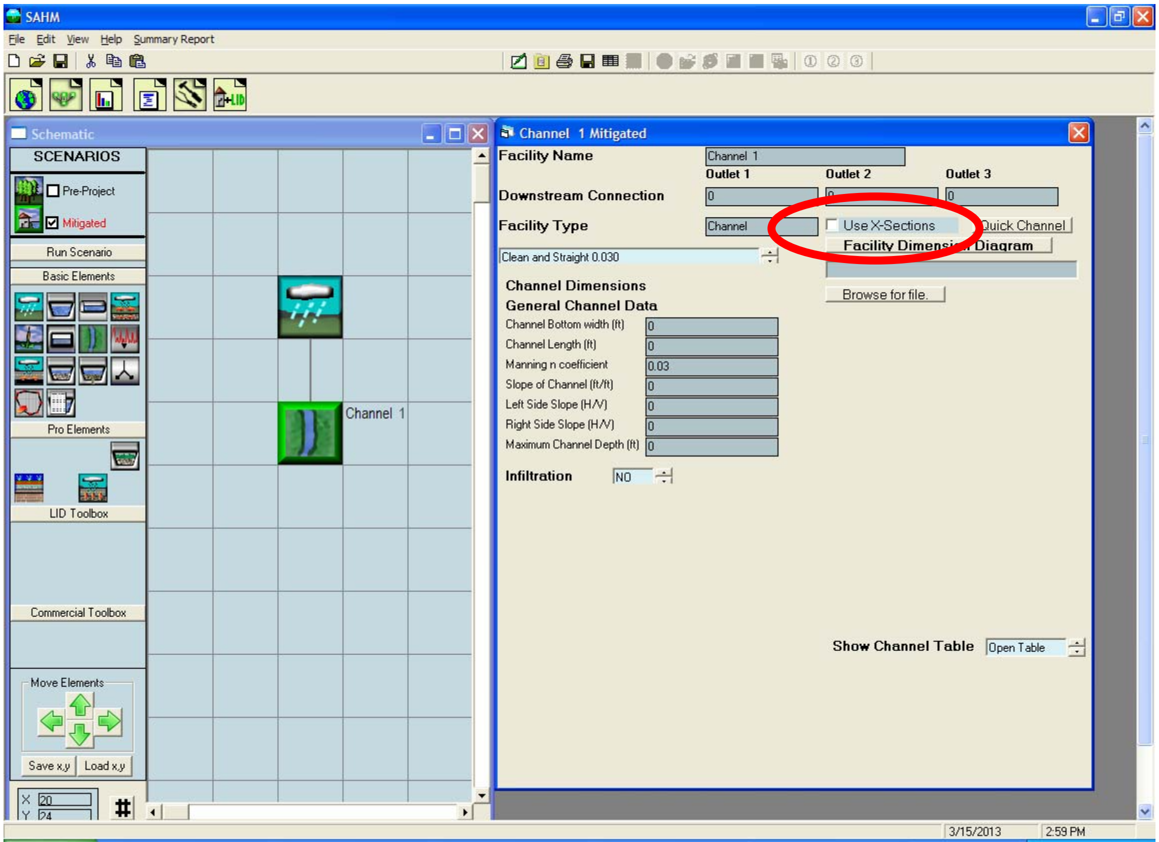
Channel input information:

Channel Bottom Width (ft): Open channel bottom width.
Channel Length (ft): Open channel length.
Manning's n coefficient: Open channel roughness coefficient (user menu selected or input).
Slope of Channel (ft/ft): Open channel bottom slope.
Left Side Slope of Channel (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical channel sides.
Right Side Slope of Channel (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical channel sides.
Maximum Channel Depth (ft): Height from bottom of channel to top of channel bank.

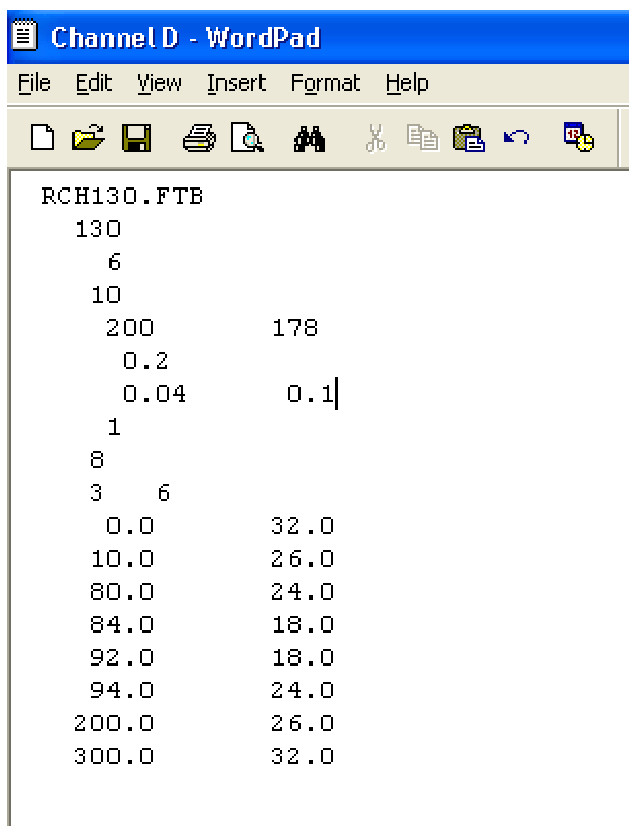
Infiltration: Yes (infiltration into the underlying native soil)
Measured Infiltration Rate (in/hr): Native soil infiltration rate.
Infiltration Reduction Factor: 1/Native soil infiltration rate safety factor (see page 74).
Use Wetted Surface Area (sidewalls): Yes, if infiltration through the channel side slopes is allowed.

If infiltration is used then the user should consult the Infiltration discussion on page 74.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.



If the “Use X-Sections” option is selected then the user is required to create a cross-section input file outside of SAHM.




```
RCH130.FTB
  130
    6
   10
     200        178
       0.2
       0.04        0.1
    1
  8
  3    6
   0.0        32.0
  10.0        26.0
  80.0        24.0
  84.0        18.0
  92.0        18.0
  94.0        24.0
 200.0        26.0
 300.0        32.0
```

Note: This option uses the XS2 program developed by AQUA TERRA Consultants to create the channel’s stage-storage-discharge table.

The text file should be created in the following format:

Line 1 (RCH130.FTB) starts in column 1. Lines 2-4 end in column 5. It recommends that the user copies the first four lines exactly as they are.

Line 5 lists first the upstream elevation of the channel and then the downstream elevation. The upstream elevation value ends in column 7; the downstream in column 17.

Line 6 is the length of the channel in miles; the value must be between column 1 and column 10.

Line 7 is the Manning's n (roughness) values for first the channel and then the floodplain. The first value must be between column 1 and column 10; the second value between 11 and 20.

Line 8 specifies how many cross sections are used to define the channel. For this example only one is specified.

Line 9 specifies how many cross section values (station and elevation) there are in the input file. In this example the number is 8. The user can specify up to a maximum of 50 cross section values.

Line 10 identifies the top of bank for both the right and left side of the channel. In this example the top of bank is at values 3 (80.0, 24.0) and 6 (94.0, 24.0). This means that all elevations below 24.0 are in the channel and use the channel's Manning's n value of 0.04 and all elevations above 24.0 are in the floodplain and use the floodplain's Manning's n value of 0.10. The transition elevations (24.0) do not have to be identical for both the left and right banks, but they should at least be close.

Below Line 10 are the eight lines of cross section values, listing first station (feet) and then elevation (feet). The station is cumulative distance from an arbitrary datum at the left edge of the floodplain (looking upstream). The first station value does not have to be zero. The elevation value corresponds to the specific station value. The channel must have the lowest elevation values. The channel bottom does not have to be flat; it can be V-shaped with a single value representing the deepest location.

If there are multiple cross sections the user would add another set of data starting with Line 9 after the last cross section value.

Note: The final stage-storage-discharge table created by this method should be checked to make sure that the table's stage, storage, and discharge values meet the criteria specified below:

1. Stage (feet) must start at zero and increase with each row. The incremental increase does not have to be consistent.

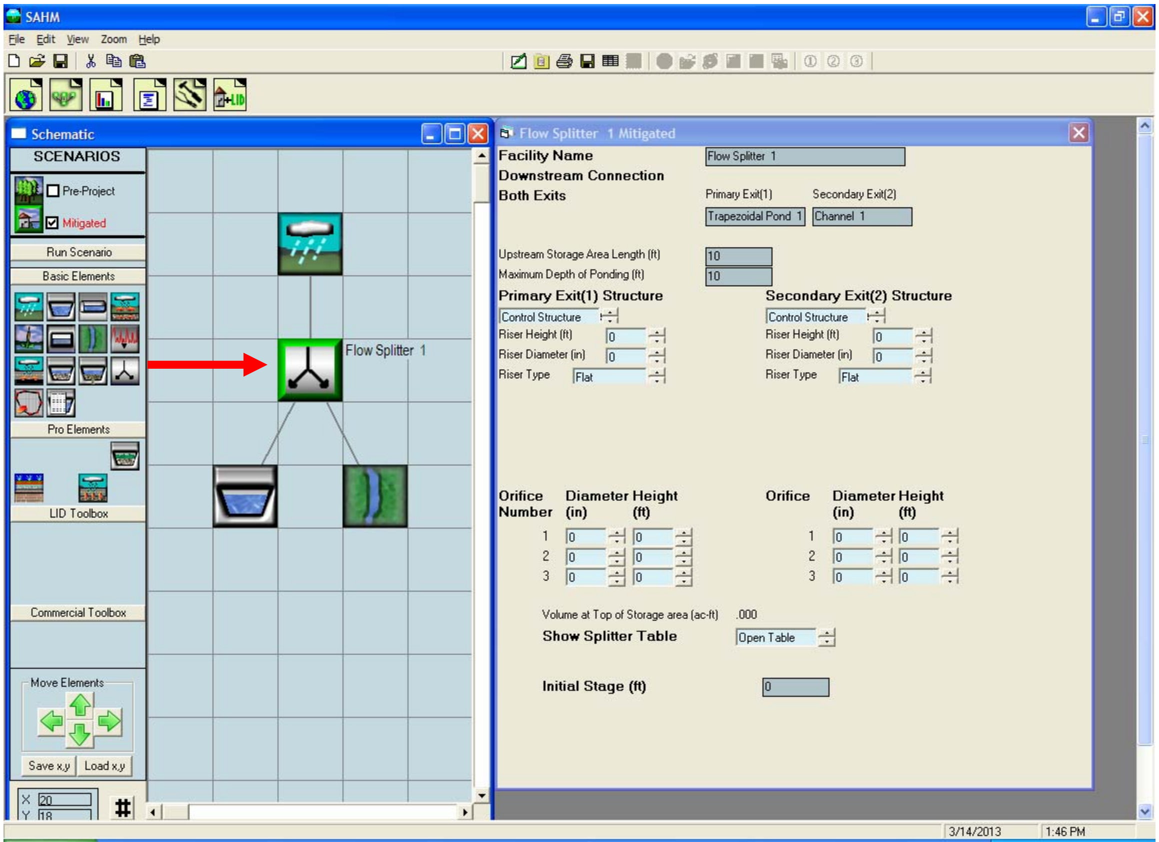
2. Storage (acre-feet) must start at zero and increase with each row. Storage values should be physically based on the corresponding depth and surface area, but SAHM does not check externally generated storage values.

3. Discharge (cfs) must start at zero. Discharge does not have to increase with each row. It can stay constant or even decrease. Discharge cannot be negative. Discharge should be based on the outlet structure's physical dimensions and characteristics, but SAHM does not check externally generated discharge values.

4. Surface area (acres) is only used if precipitation to and evaporation from the facility are applied.

If any of these criteria are violated SAHM will produce an error message. If that occurs the cross section values (station and elevation) will need to be adjusted to produce a stage-storage-discharge table that meets the above criteria.

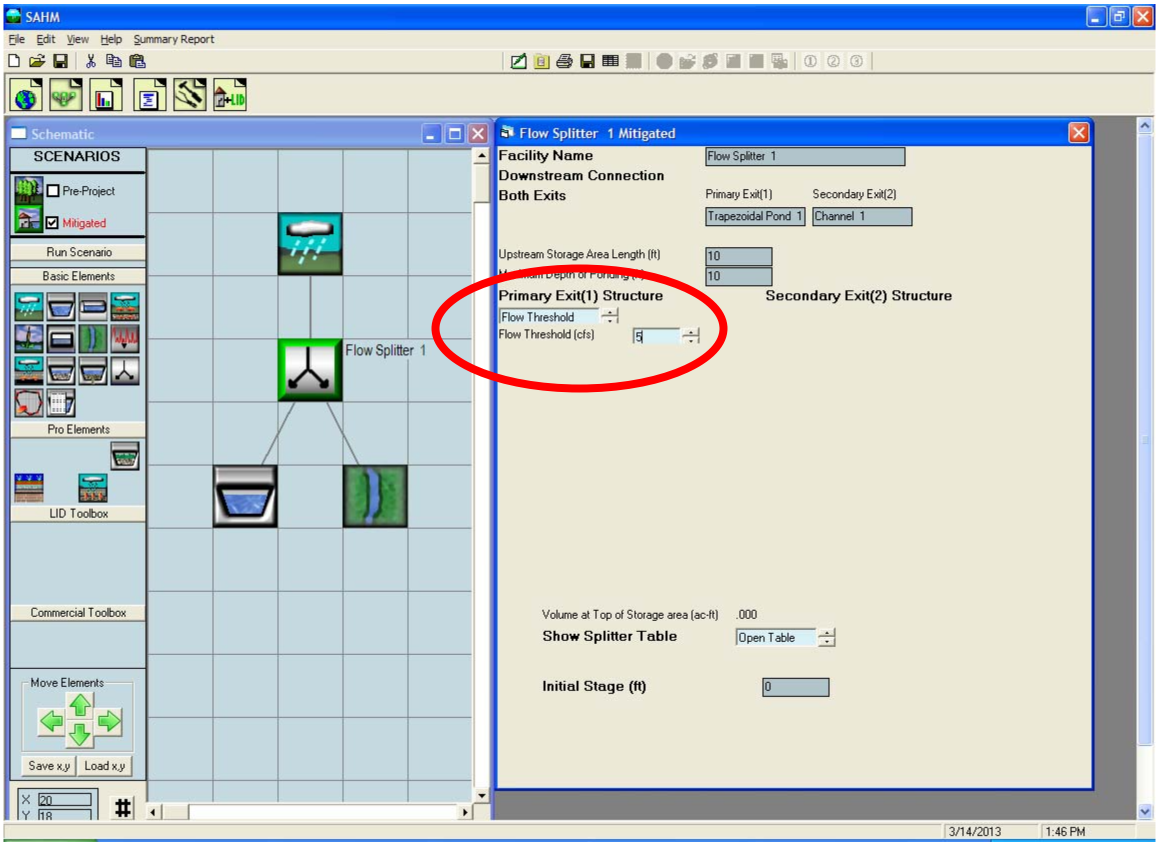
FLOW SPLITTER ELEMENT



The flow splitter divides the runoff and sends it to two difference destinations. The splitter has a primary exit (exit 1) and a secondary exit (exit 2). The user defines how the flow is split between these two exits.

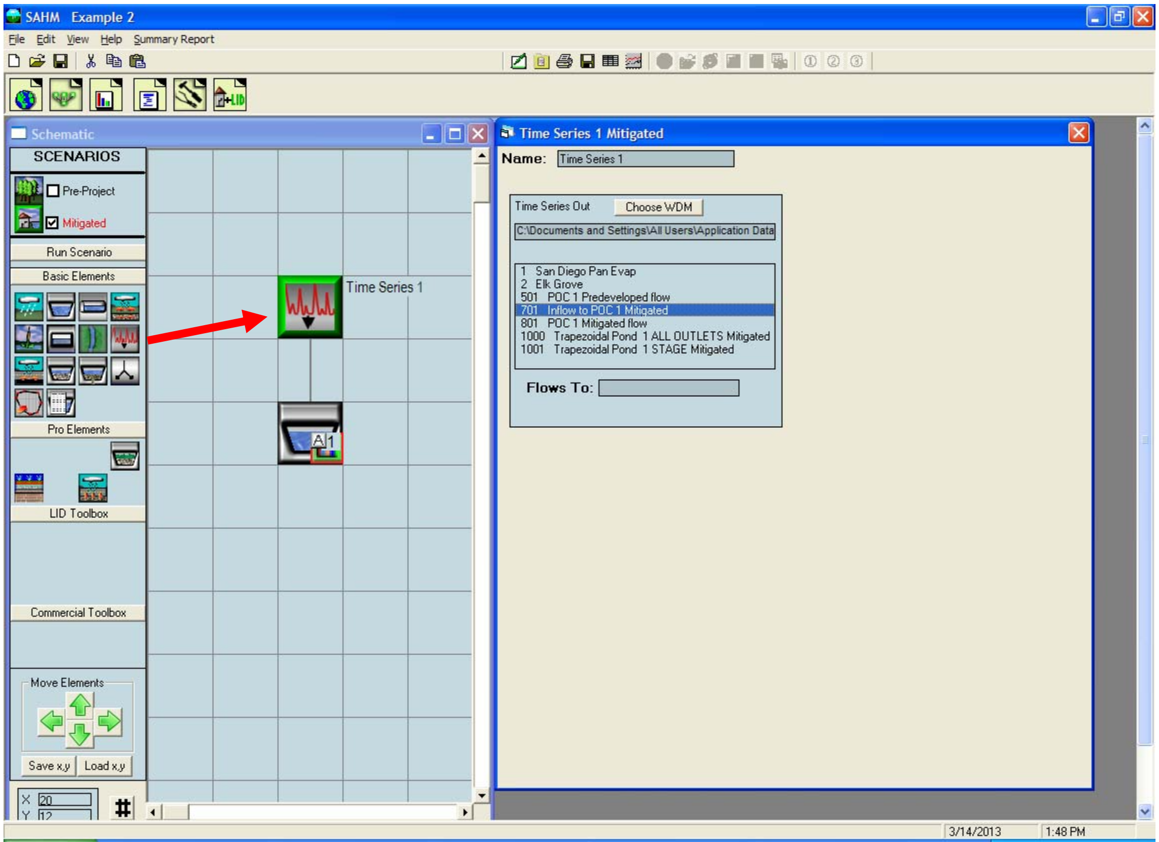
The user can define a flow control structure with a riser and one to three orifices for each exit. The flow control structure works the same way as the pond outlet structure, with the user setting the riser height and diameter, the riser weir type (flat, rectangular notch, V-notch, or Sutro), and the orifice diameter and height.

For more information on riser notch options and orifices see discussion in OUTLET STRUCTURE CONFIGURATIONS section.



The second option is that the flow split can be based on a flow threshold. The user sets the flow threshold value (cfs) for exit 1 at which flows in excess of the threshold go to exit 2. For example, if the flow threshold is set to 5 cfs then all flows less than or equal to 5 cfs go to exit 1. Exit 2 gets only the excess flow above the 5 cfs threshold (total flow minus exit 1 flow).

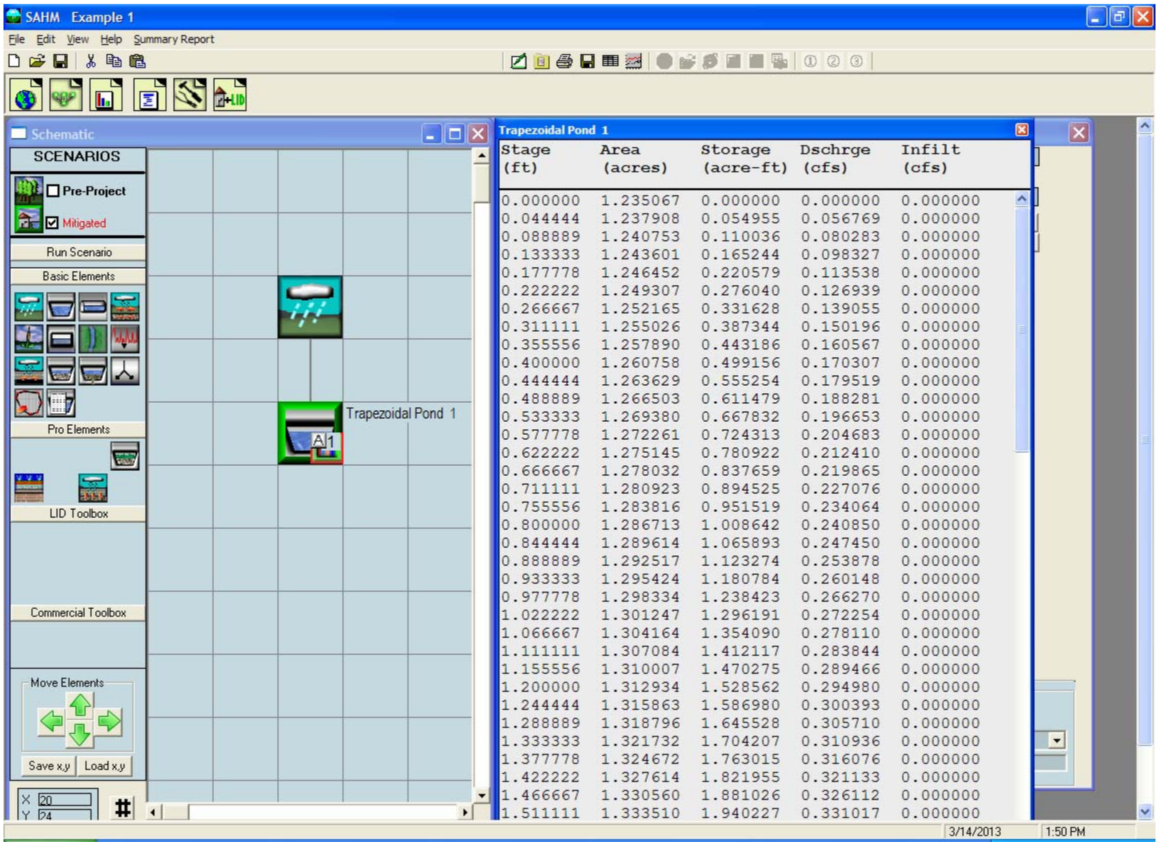
TIME SERIES ELEMENT



SAHM uses time series of precipitation, evaporation, and runoff stored in its database (HSPF WDM file). The user has the option to create or use a time series file external from SAHM in SAHM. This may be a time series of flow values created by another HSPF model. An example is offsite runoff entering a project site. If this offsite runoff is in an existing WDM file and is the same period as SAHM data and the same simulation time step (hourly) then it can be linked to SAHM model using the Time Series element.

To link the external time series to SAHM the user clicks on the Choose WDM button and identifies the external WDM file. The external WDM's individual time series files are shown in the Time Series Out box. The selected input dataset is the time series that will be used by SAHM.

STAGE-STORAGE-DISCHARGE TABLE



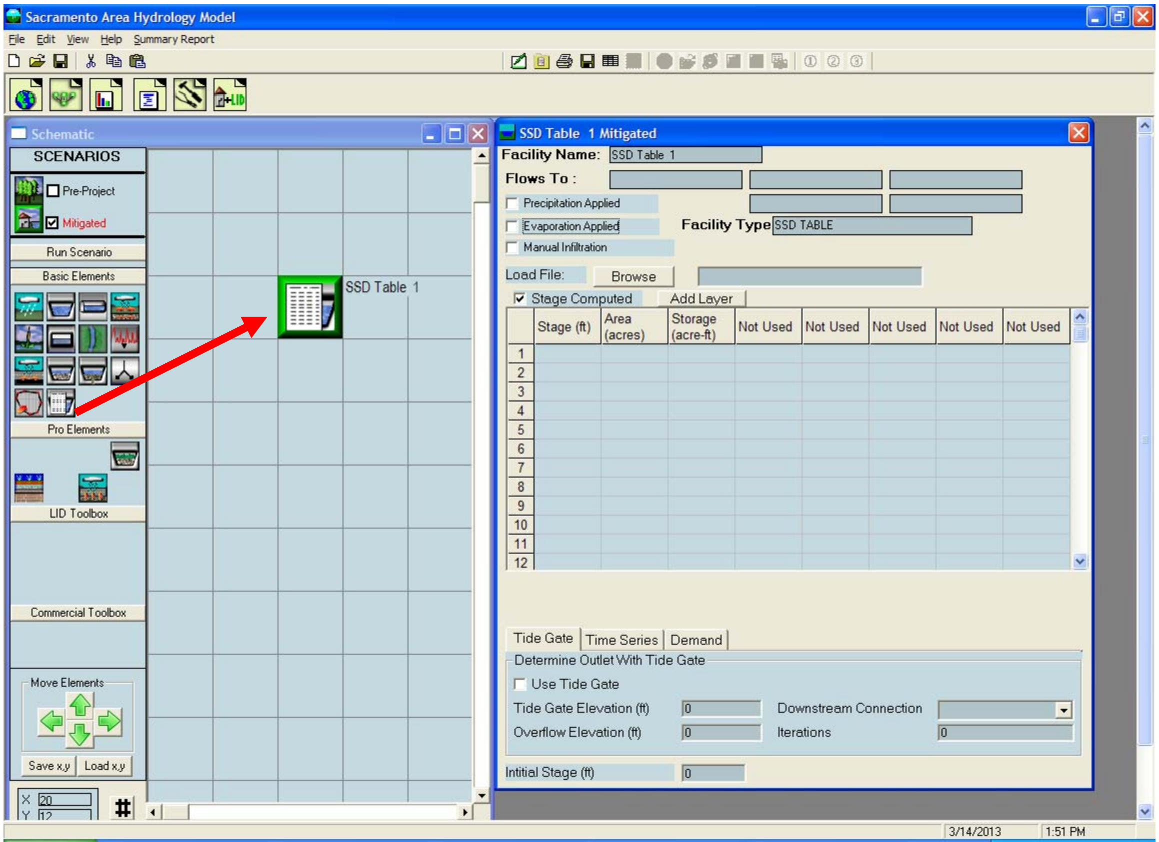
Stage (ft)	Area (acres)	Storage (acre-ft)	Dschrge (cfs)	Infilt (cfs)
0.000000	1.235067	0.000000	0.000000	0.000000
0.044444	1.237908	0.054955	0.056769	0.000000
0.088889	1.240753	0.110036	0.080283	0.000000
0.133333	1.243601	0.165244	0.098327	0.000000
0.177778	1.246452	0.220579	0.113538	0.000000
0.222222	1.249307	0.276040	0.126939	0.000000
0.266667	1.252165	0.331628	0.139055	0.000000
0.311111	1.255026	0.387344	0.150196	0.000000
0.355556	1.257890	0.443186	0.160567	0.000000
0.400000	1.260758	0.499156	0.170307	0.000000
0.444444	1.263629	0.555254	0.179519	0.000000
0.488889	1.266503	0.611479	0.188281	0.000000
0.533333	1.269380	0.667832	0.196653	0.000000
0.577778	1.272261	0.724313	0.204683	0.000000
0.622222	1.275145	0.780922	0.212410	0.000000
0.666667	1.278032	0.837659	0.219865	0.000000
0.711111	1.280923	0.894525	0.227076	0.000000
0.755556	1.283816	0.951519	0.234064	0.000000
0.800000	1.286713	1.008642	0.240850	0.000000
0.844444	1.289614	1.065893	0.247450	0.000000
0.888889	1.292517	1.123274	0.253878	0.000000
0.933333	1.295424	1.180784	0.260148	0.000000
0.977778	1.298334	1.238423	0.266270	0.000000
1.022222	1.301247	1.296191	0.272254	0.000000
1.066667	1.304164	1.354090	0.278110	0.000000
1.111111	1.307084	1.412117	0.283844	0.000000
1.155556	1.310007	1.470275	0.289466	0.000000
1.200000	1.312934	1.528562	0.294980	0.000000
1.244444	1.315863	1.586980	0.300393	0.000000
1.288889	1.318796	1.645528	0.305710	0.000000
1.333333	1.321732	1.704207	0.310936	0.000000
1.377778	1.324672	1.763015	0.316076	0.000000
1.422222	1.327614	1.821955	0.321133	0.000000
1.466667	1.330560	1.881026	0.326112	0.000000
1.511111	1.333510	1.940227	0.331017	0.000000

The stage-storage-discharge table hydraulically represents any facility that requires stormwater routing. The table is automatically generated by SAHM when the user inputs storage facility dimensions and outlet structure information. SAHM generates 91 lines of stage, surface area, storage, surface discharge, and infiltration values starting at a stage value of zero (facility bottom height) and increasing in equal increments to the maximum stage value (facility effective depth).

When the user or SAHM changes a facility dimension (for example, bottom length) or an orifice diameter or height the model immediately recalculates the stage-storage-discharge table.

The user can input to SAHM a stage-storage-discharge table created outside of SAHM. To use a stage-storage-discharge table created out of SAHM the SSD Table element is required. See the SSD Table element description below for more information on how to load such a table to SAHM program.

SSD TABLE ELEMENT



The SSD Table is a stage-storage-discharge table externally produced by the user and is identical in format to the stage-storage-discharge tables generated internally by SAHM for ponds, vaults, tanks, and channels.

The easiest way to create a SSD Table outside of SAHM is to use a spreadsheet with a separate column for stage, surface area, storage, and discharge (in that order). Save the spreadsheet file as a space or comma-delimited file. A text file can also be created, if more convenient.

The SSD Table must use the following units:
Stage: feet
Surface Area: acres
Storage: acre-feet
Discharge: cubic feet per second (cfs)

A fifth column can be used to create a second discharge (cfs). This second discharge can be infiltration or a second surface discharge.

Certain rules apply to the SSD Table whether it is created inside or outside of SAHM. These rules are:

5. Stage (feet) must start at zero and increase with each row. The incremental increase does not have to be consistent.

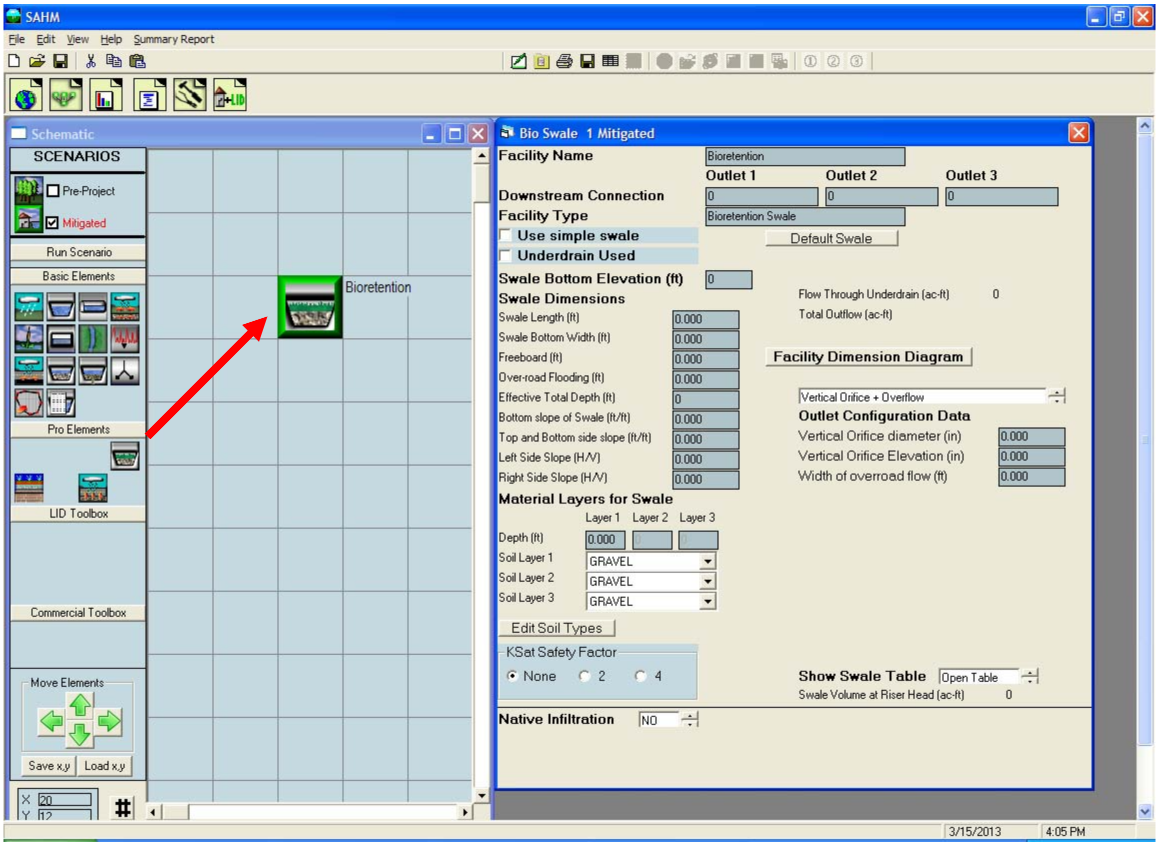
6. Storage (acre-feet) must start at zero and increase with each row. Storage values should be physically based on the corresponding depth and surface area, but SAHM does not check externally generated storage values.

7. Discharge (cfs) must start at zero. Discharge does not have to increase with each row. It can stay constant or even decrease. Discharge cannot be negative. Discharge should be based on the outlet structure's physical dimensions and characteristics, but SAHM does not check externally generated discharge values.

8. Surface area (acres) is only used if precipitation to and evaporation from the facility are applied.

To input an externally generated SSD Table, first create and save the table outside of SAHM. Use the Browse button to locate and load the file into SAHM.

BIORETENTION/RAIN GARDEN ELEMENT



The bioretention element is also known as a rain garden. A bioretention facility is a depression in which the native soils have been excavated and replaced with amended or engineered soil. On the surface of the bioretention facility there is either a riser with a discharge pipe or a weir controls the surface discharge from the bioretention. Ponding of stormwater runoff is allowed, encouraging it to infiltrate into the amended soil. Infiltration from the amended soil to the native soil is also possible, depending on the properties of the native soil. Bioretention also can include an underdrain pipe.

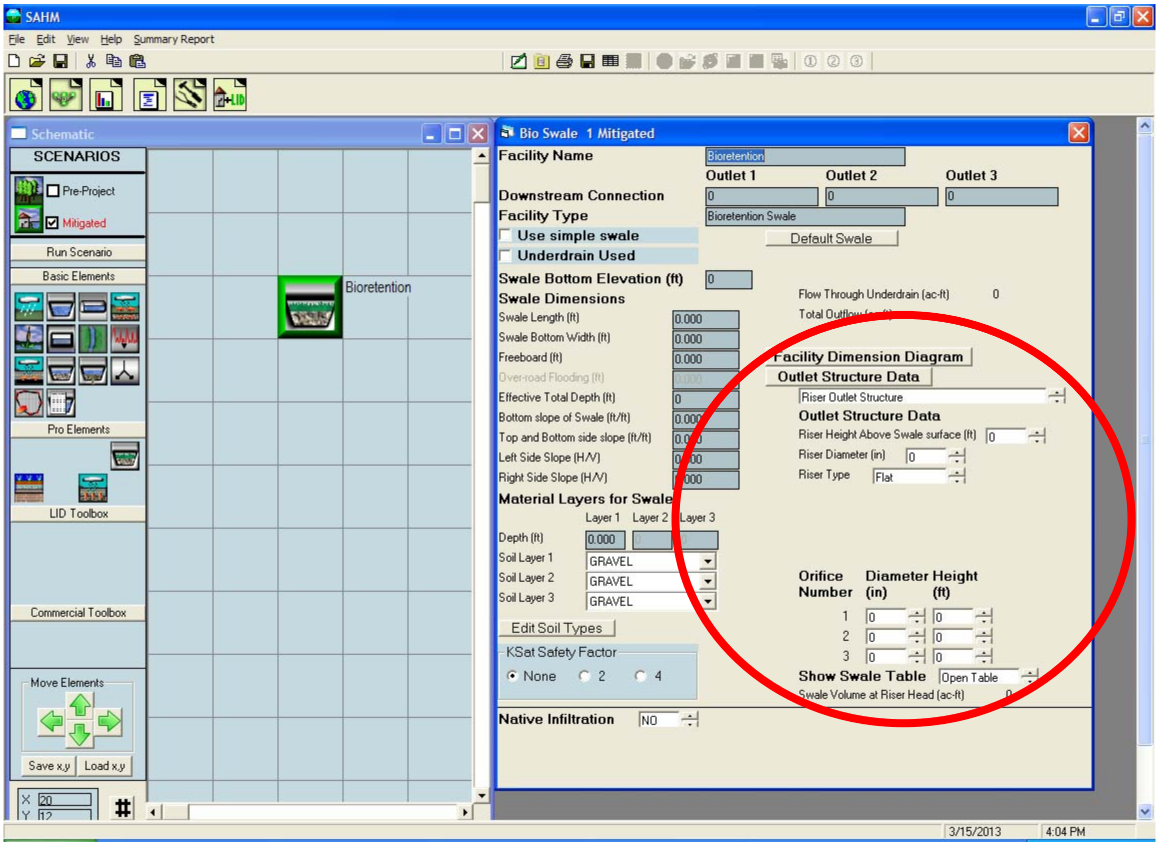
Note: a bioretention facility fills from the surface down to the bottom. By comparison, a gravel trench bed is assumed to fill with stormwater from the bottom of the trench to the top. This makes a difference in how quickly water reaches the underdrain and the native soil and exits the bioretention amended soil via either discharge route.

The user can select one of two outlet configurations:

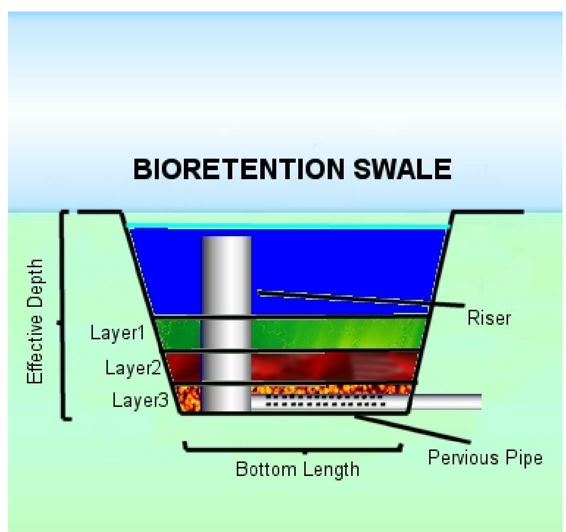
1. Riser outlet structure
2. Vertical orifice + overflow

The user is required to enter the following information about the bioretention facility, depending on the outlet configuration selected:

Riser outlet structure:



The bioretention dimensions are specified below.



Swale Length (ft): length dimension of bioretention surface bottom.

Swale Bottom Width (ft): width dimension of bioretention surface bottom.

Freeboard (ft): depth of surface ponding above riser height.

Effective Total Depth (ft): the total depth of the amended soil layer(s) plus riser height plus freeboard; effective total depth is computed by SAHM.

Bottom Slope of Swale (ft/ft): the slope of the swale length; must be greater than zero.

Top and Bottom Side Slopes (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical sides. Top refers to the uphill end of the bioretention facility; bottom to the downhill end.
Left Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical swale sides.
Right Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical swale sides.

The input information required for the riser outlet structure is:

Riser Height above Swale Surface (feet): depth of surface ponding before the riser is overtopped.
Riser Diameter (inches): diameter of the stand pipe.
Riser Type: Flat or Notched.
Notch Type: Rectangular, V-Notch, or Sutro.
For a rectangular notch:
Notch Height (feet): distance from the top of the weir to the bottom of the notch.
Notch Width (feet): width of notch; cannot be larger than the riser circumference.

For more information on riser notch options and orifices see discussion in OUTLET STRUCTURE CONFIGURATIONS section.

The material layer inputs are:

Layer Thickness (feet): depth of amended soil.

Type of amended soil: 24 different soil types are included; the user can also create their own soil type using the Edit Soil Type button.

Note that there can be a maximum of three different amended soil layers.

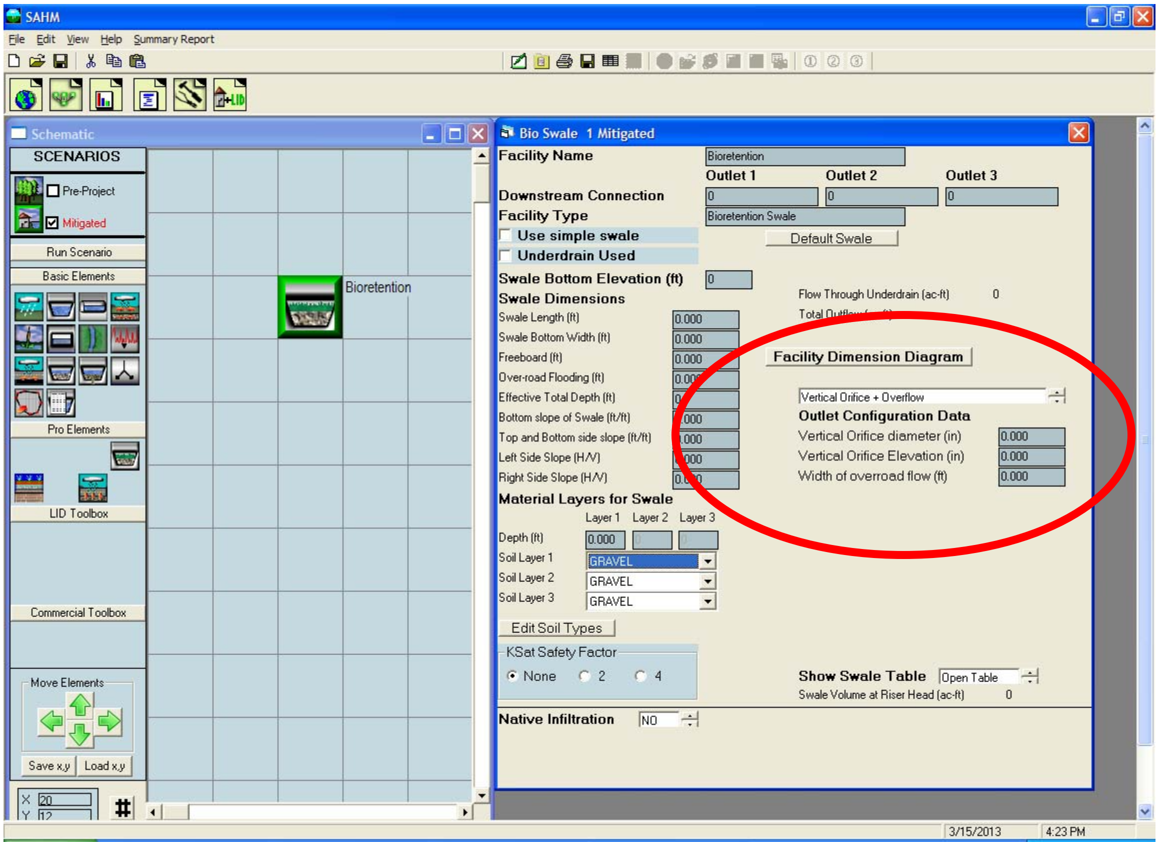
Infiltration to the native soil can be turned on by setting Native Infiltration to YES. The parameters for native soil infiltration are:

Measured Infiltration Rate (inches per hour): infiltration rate of the native soil.
Infiltration Reduction Factor: between 0 and 1 (1/Native soil infiltration rate safety factor (see page 74).
Use Wetted Surface Area (sidewalls): YES or NO; YES allows infiltration to the native soil through the sidewalls of the swale; otherwise all infiltration is through the bottom only.

If infiltration is used then the user should consult the Infiltration discussion on page 74.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.

Vertical orifice plus overflow:



The bioretention dimensions are specified below.

Swale Length (ft): length dimension of bioretention surface bottom.

Swale Bottom Width (ft): width dimension of bioretention surface bottom.

Freeboard (ft): Height from top of vertical orifice to weir.
Over-road Flooding (feet): height above weir; must be greater than zero.

Effective Total Depth (ft): the total depth of the amended soil layer(s) plus vertical orifice elevation plus vertical orifice diameter plus freeboard plus over-road flooding height; effective total depth is computed by SAHM.

Bottom Slope of Swale (ft/ft): the slope of the swale length; must be greater than zero.

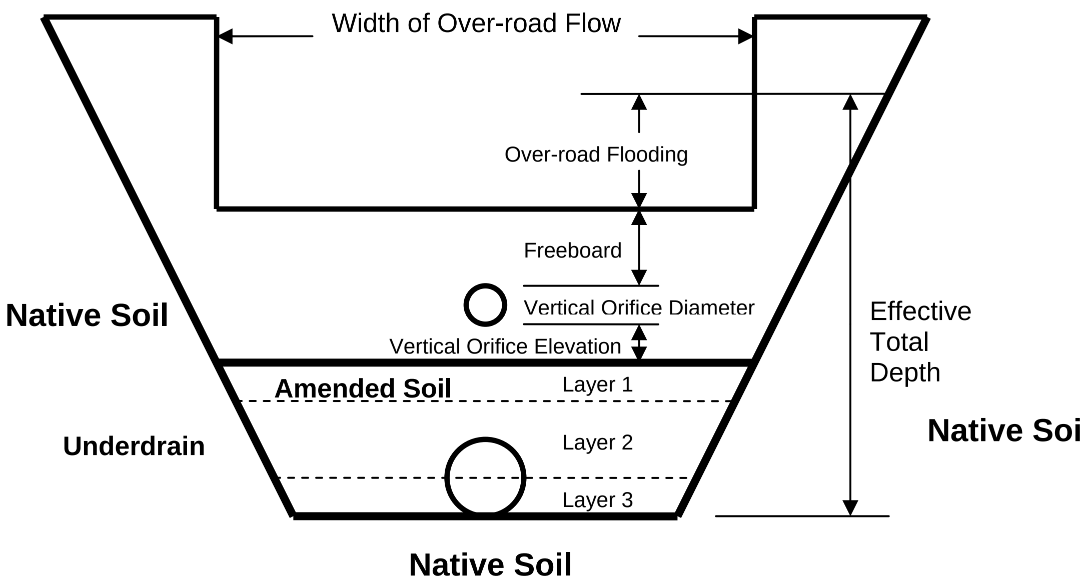
Top and Bottom Side Slopes (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical sides. Top refers to the uphill end of the bioretention facility; bottom to the downhill end.
Left Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical swale sides.

Right Side Slope (ft/ft): H/V ratio of horizontal distance to vertical; 0 (zero) for vertical swale sides.

The input information required for the vertical orifice plus overflow option is:

Vertical Orifice Diameter (inches): diameter of vertical opening below the weir.
Vertical Orifice Elevation (inches): vertical distance from the top of the amended soil surface to the bottom of the vertical orifice.
Width of Over-road Flow (feet): weir/street length; must be greater than zero.

Diagram of bioretention with vertical orifice plus overflow:



The material layer inputs are:

Layer Thickness (feet): depth of amended soil.

Type of amended soil: 24 different soil types are included; the user can also create their own soil type using the Edit Soil Type button.

Note that there can be a maximum of three different amended soil layers.

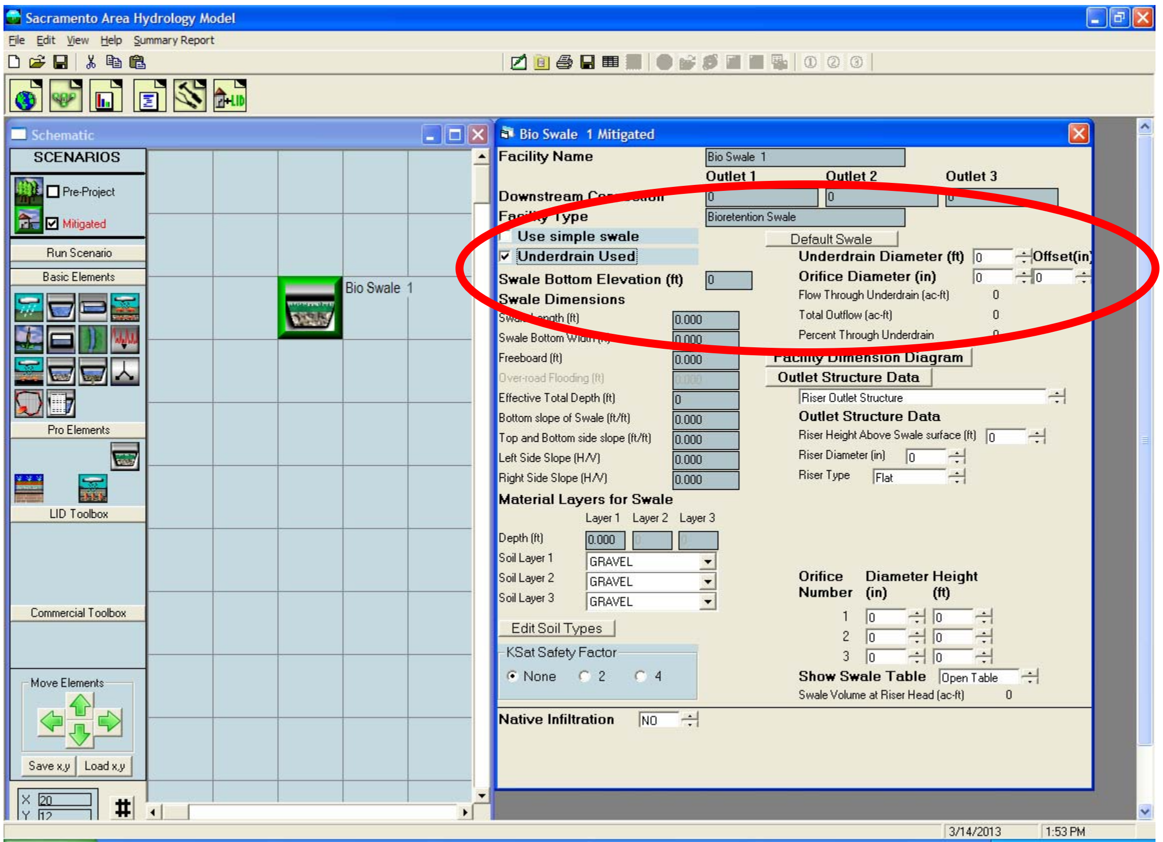
Infiltration to the native soil can be turned on by setting Native Infiltration to YES. The parameters for native soil infiltration are:

Measured Infiltration Rate (inches per hour): infiltration rate of the native soil.
Infiltration Reduction Factor: between 0 and 1 (1/Native soil infiltration rate safety factor (see page 74).

Use Wetted Surface Area (sidewalls): YES or NO; YES allows infiltration to the native soil through the sidewalls of the swale; otherwise all infiltration is through the bottom only.

If infiltration is used then the user should consult the Infiltration discussion on page 74.

NOTE: See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of the appropriate infiltration reduction factor.



To use the underdrain click the Underdrain Used box and input an underdrain pipe diameter (feet), underdrain outlet orifice diameter (inches), and the offset or height above the bottom of the lowest amended soil layer.

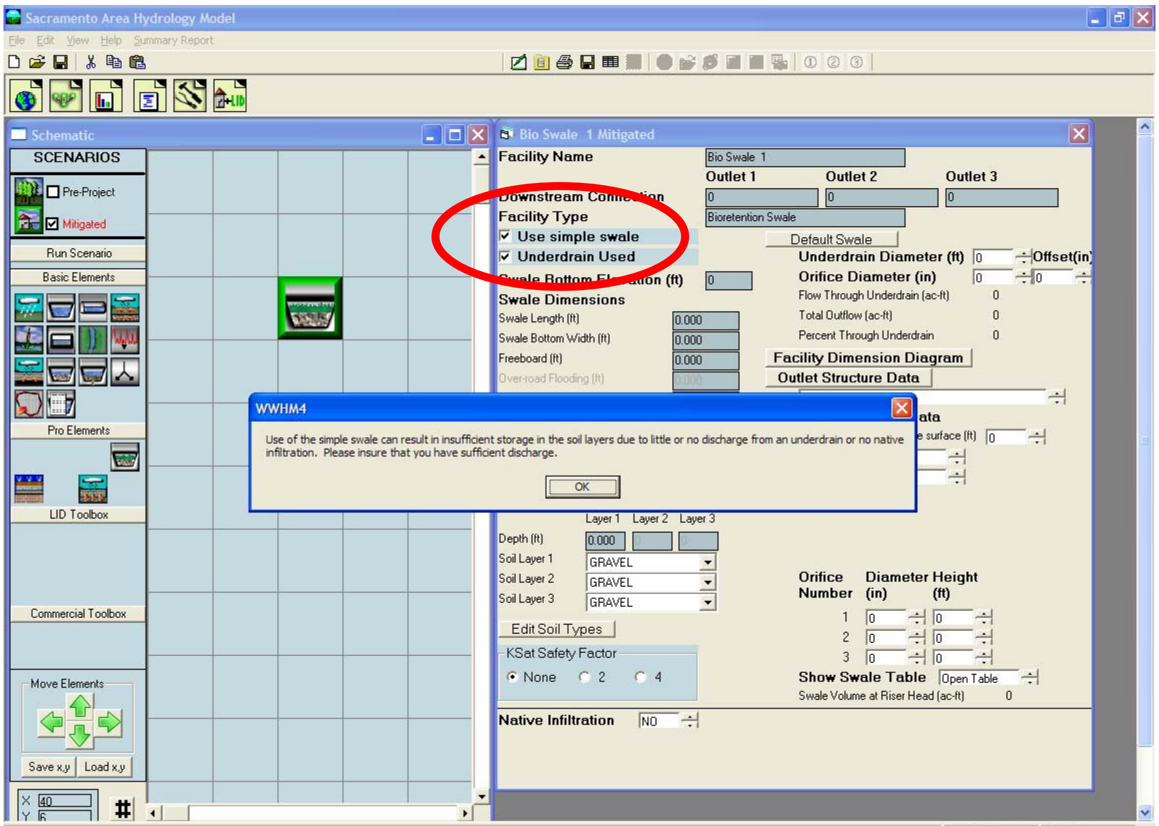
The amended soil layer fills with stormwater from the top on down to where it can drain to the native soil (if Native Infiltration is set to YES) and/or the underdrain pipe (if Underdrain Used box is checked).

Water enters the underdrain when the amended soil becomes saturated down to the top of the underdrain. The underdrain pipe fills and conveys water proportionally to the depth of amended soil saturation. When the amended soil is fully saturated the underdrain pipe

is at full capacity. Discharge from the underdrain pipe is controlled by the underdrain orifice diameter.

If native infiltration is turned on then native infiltration will start when/if:

1. Water starts to fill the underdrain (if an underdrain is used).
2. Water enters the amended soil (if Use Wetted Surface Area (sidewalls) is set to YES).
3. Water saturates the amended soil layer(s) to 2/3rds of the total amended soil depth (if there is no underdrain and Wetted Surface Area is set to NO).



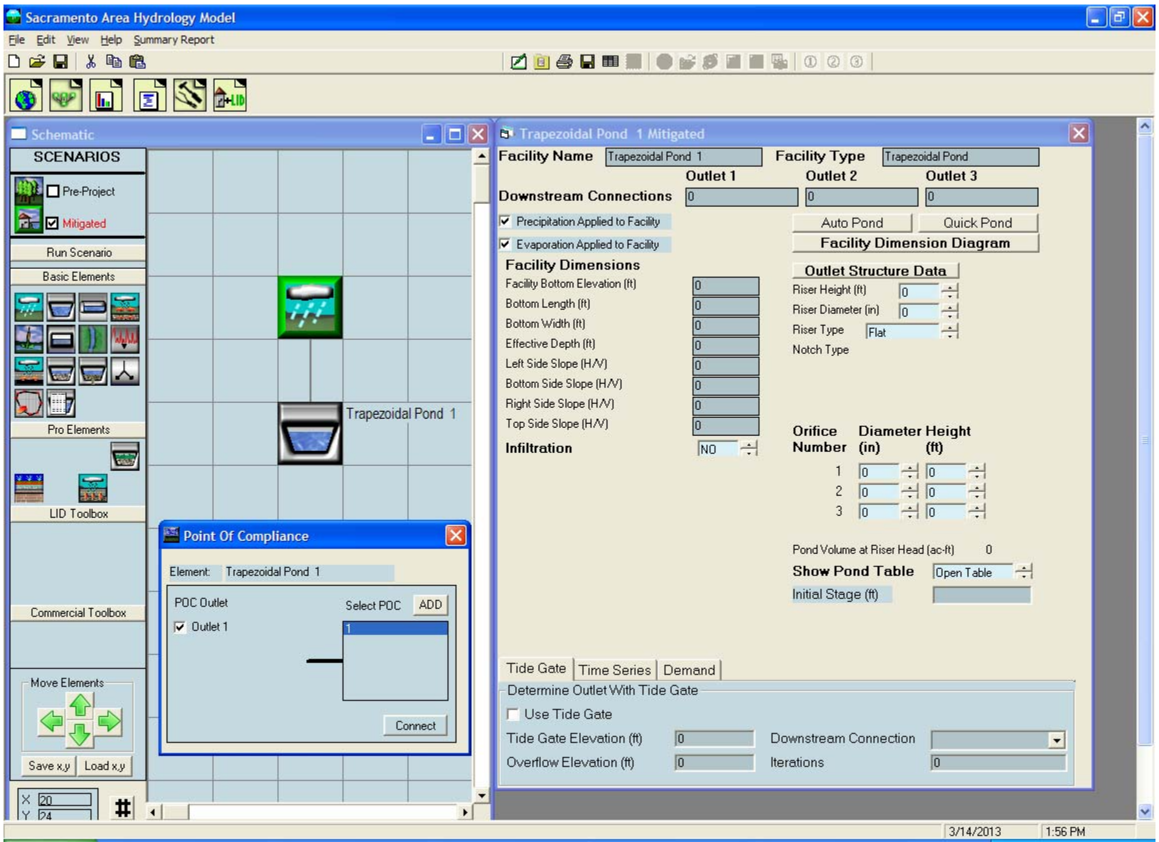
There is a simple swale option. It is computationally much faster than the standard bioretention swale. Before using the simple swale option read the note on the screen and the information below to understand the limitations of the simple swale.

The standard bioretention swale routine checks the available amended soil storage and compares it with the inflow rate. Because of the check done each time step simulations using bioretention elements take much longer than simulations not using bioretention elements. Simulations that normally take only seconds may take multiple minutes when one or more bioretention elements are added, depending on the computational speed of the computer used.

One solution to this problem is to use the simple bioretention swale option (check the Use Simple Swale box). The simple bioretention swale does not check for volume. It is less accurate than the standard swale. Tests have shown that the simple swale option should only be used when the swale area (and volume) is relatively small compared to the contributing basin area. If in doubt, model the bioretention both ways and see how close the simple answer is to the standard method. The standard method will always be more accurate than the simple swale.

POINT OF COMPLIANCE

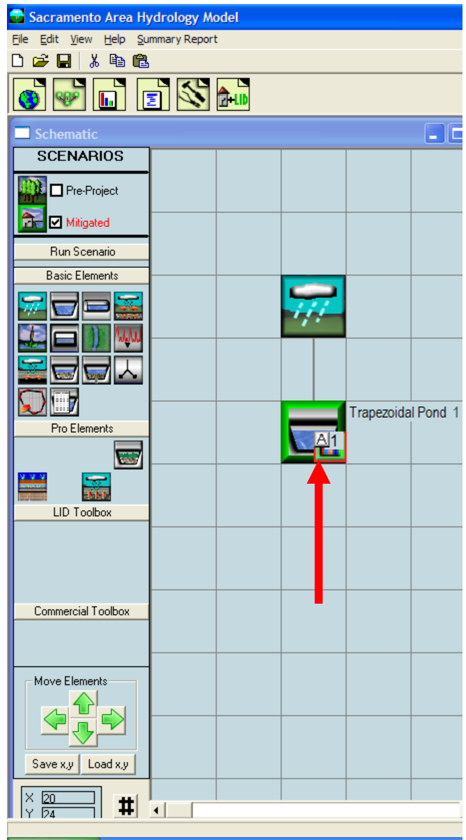
SAHM allows for multiple points of compliance (maximum of 59) in a single project. A point of compliance is defined as the location at which the Pre-project and Mitigated flows will be analyzed for compliance with the flow control standard.



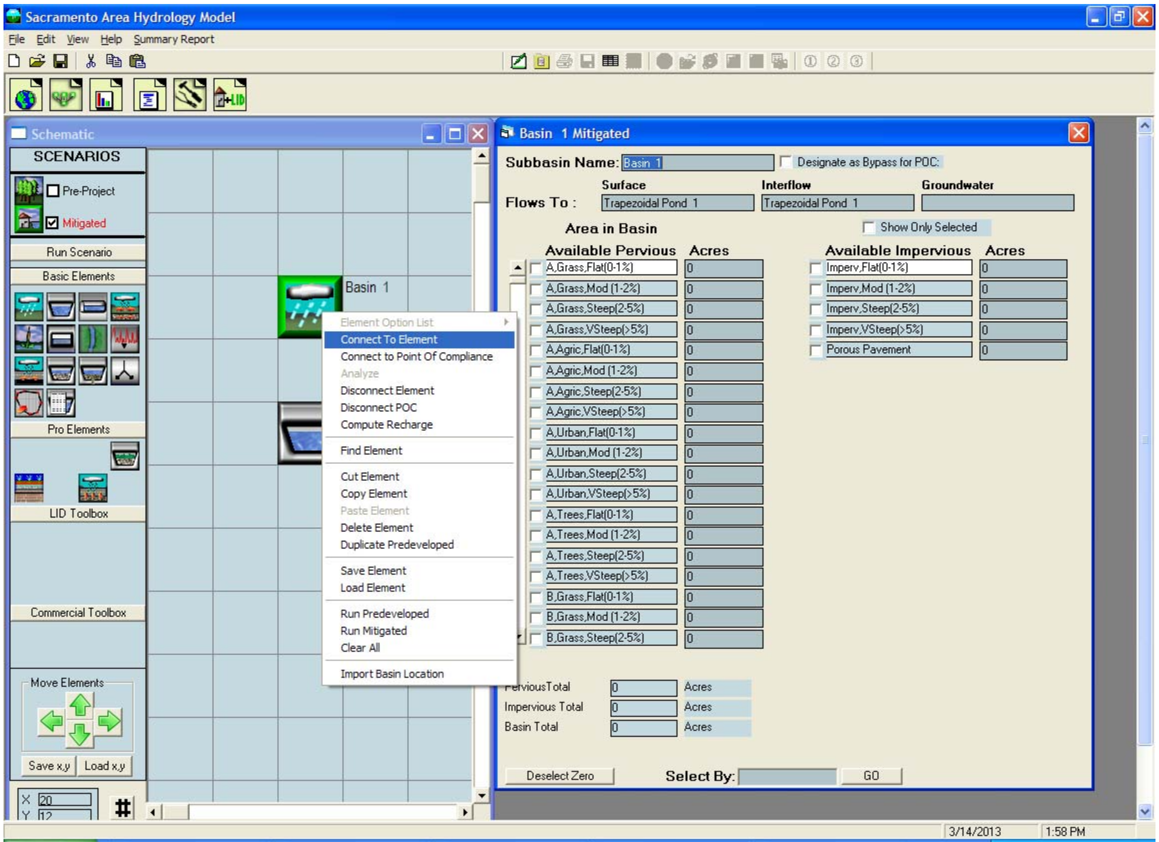
The point of compliance is selected by right clicking on the element at which the compliance analysis will be made. In the example above, the point of compliance analysis will be conducted at the outlet of the trapezoidal pond.

Once the point of compliance has been selected the element is modified on the Schematic screen to include a small box with the letter "A" (for Analysis) in the lower right corner. This identifies the outlet from this element as a point of compliance.

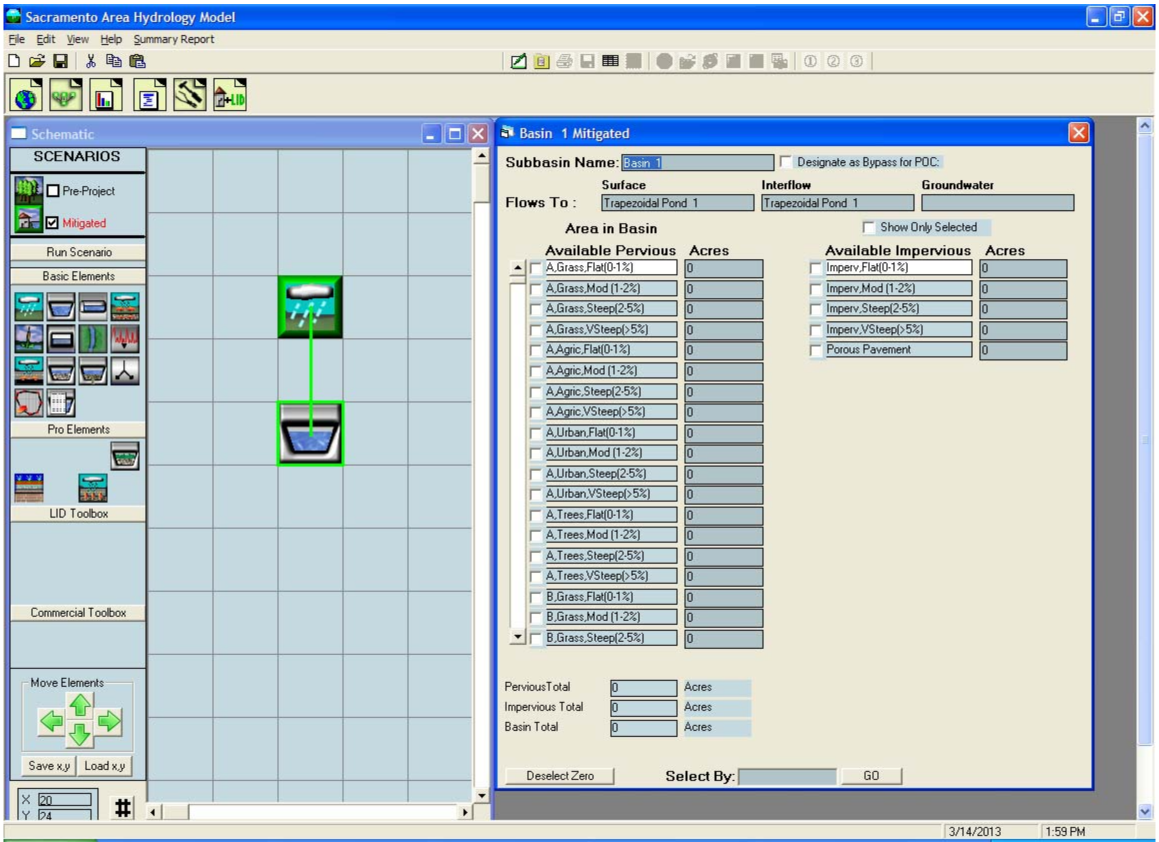
The number 1 next to the letter "A" is the number of the POC (POC 1).



CONNECTING ELEMENTS

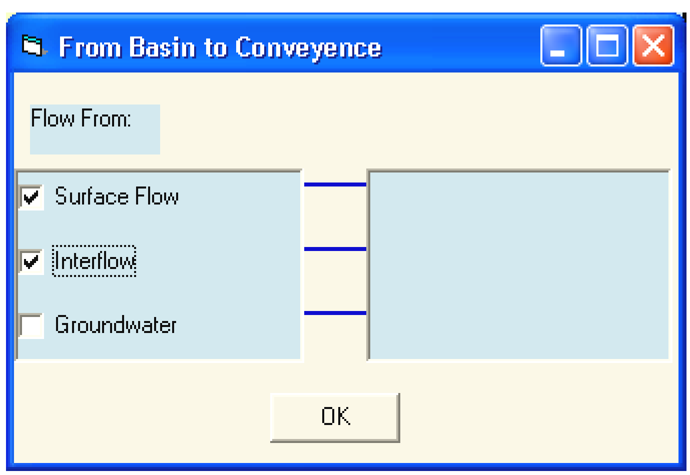


Elements are connected by right clicking on the upstream element (in this example Basin 1) and selecting and then left clicking on the Connect To Element option. By doing so SAHM extends a line from the upstream element to wherever the user wants to connect that element.

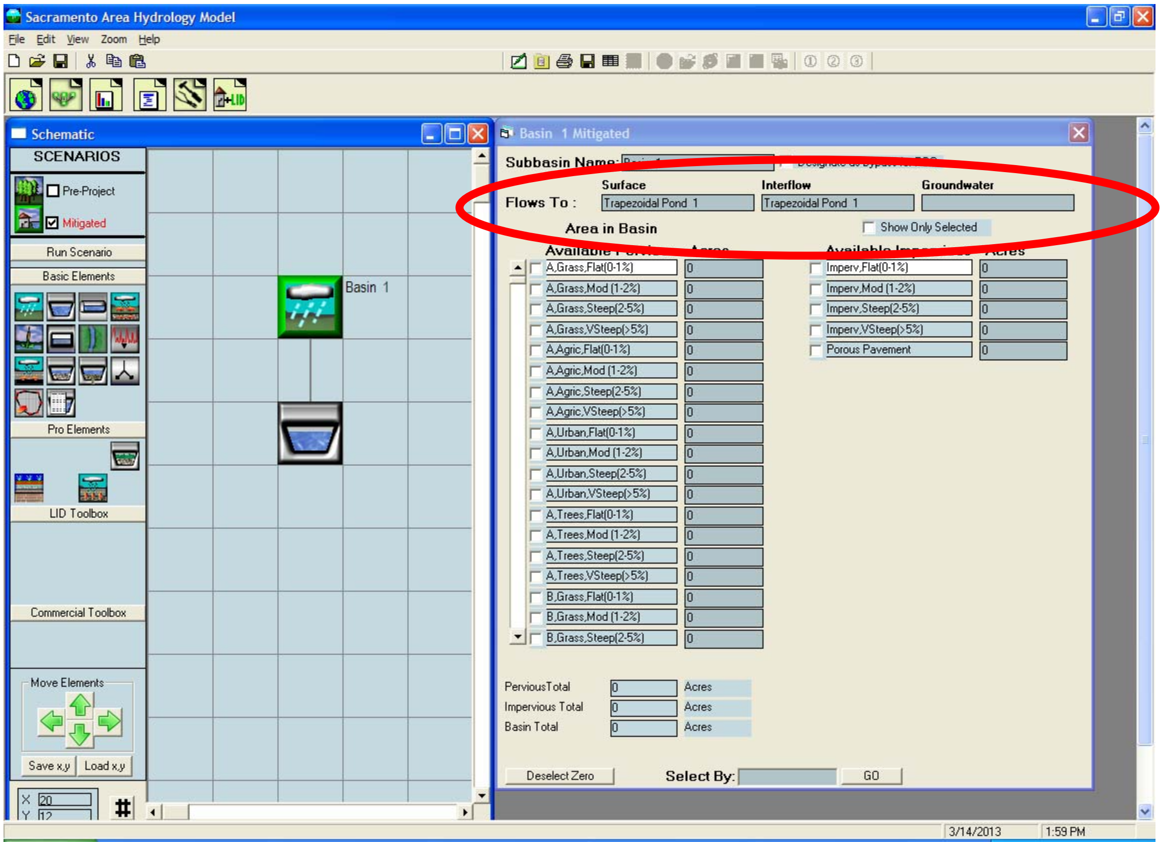


The user extends the connection line to the downstream element (in this example, a pond) and left clicks on the destination element. This action brings up the From Basin to Conveyance box that allows the user to specify which runoff components to route to the downstream element.

Stormwater runoff is defined as surface flow + interflow. Both boxes should be checked. Groundwater should not be checked for the standard land development mitigation analysis. Groundwater should only be checked when there is observed and documented base flow occurring from the upstream basin.

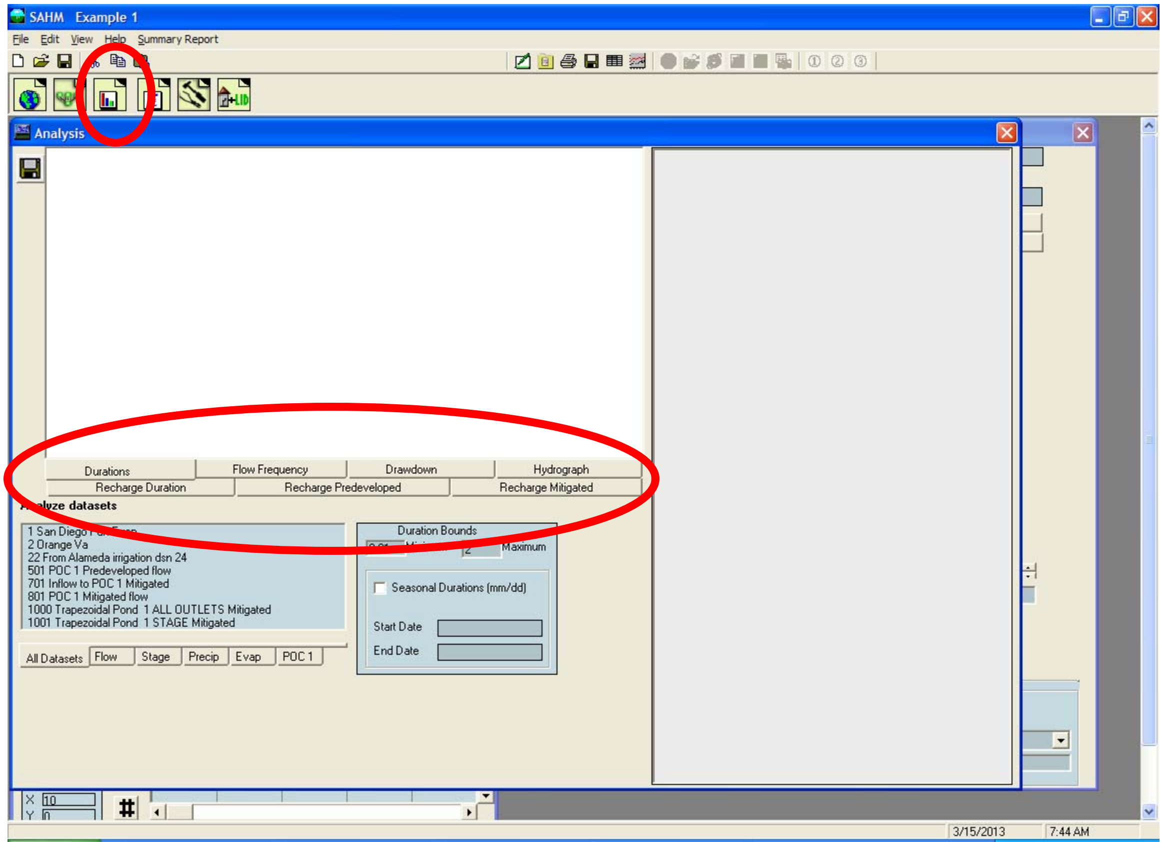


After the appropriate boxes have been checked click the OK button.



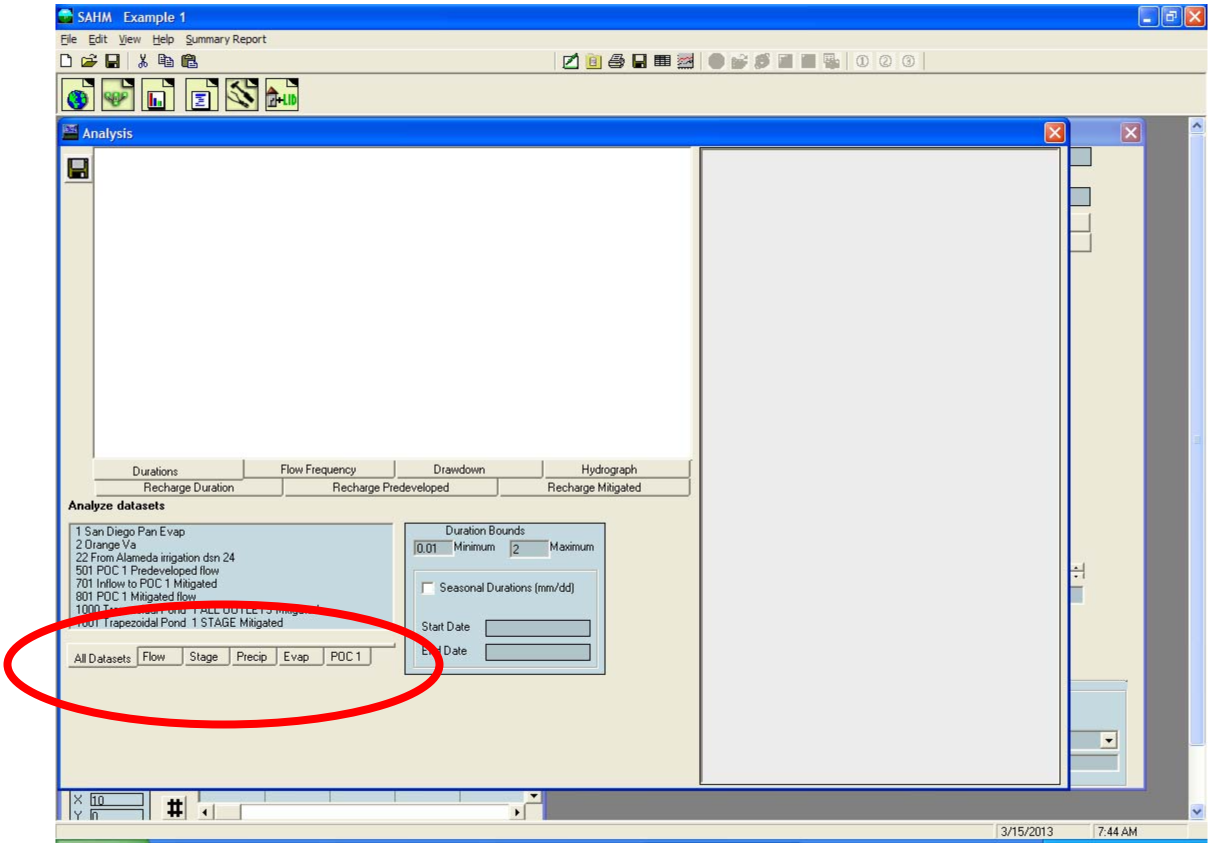
The final screen will look like the above screen. The basin information screen on the right will show that Basin 1 surface and interflow flows to Trapezoidal Pond 1 (groundwater is not connected).

ANALYSIS SCREEN



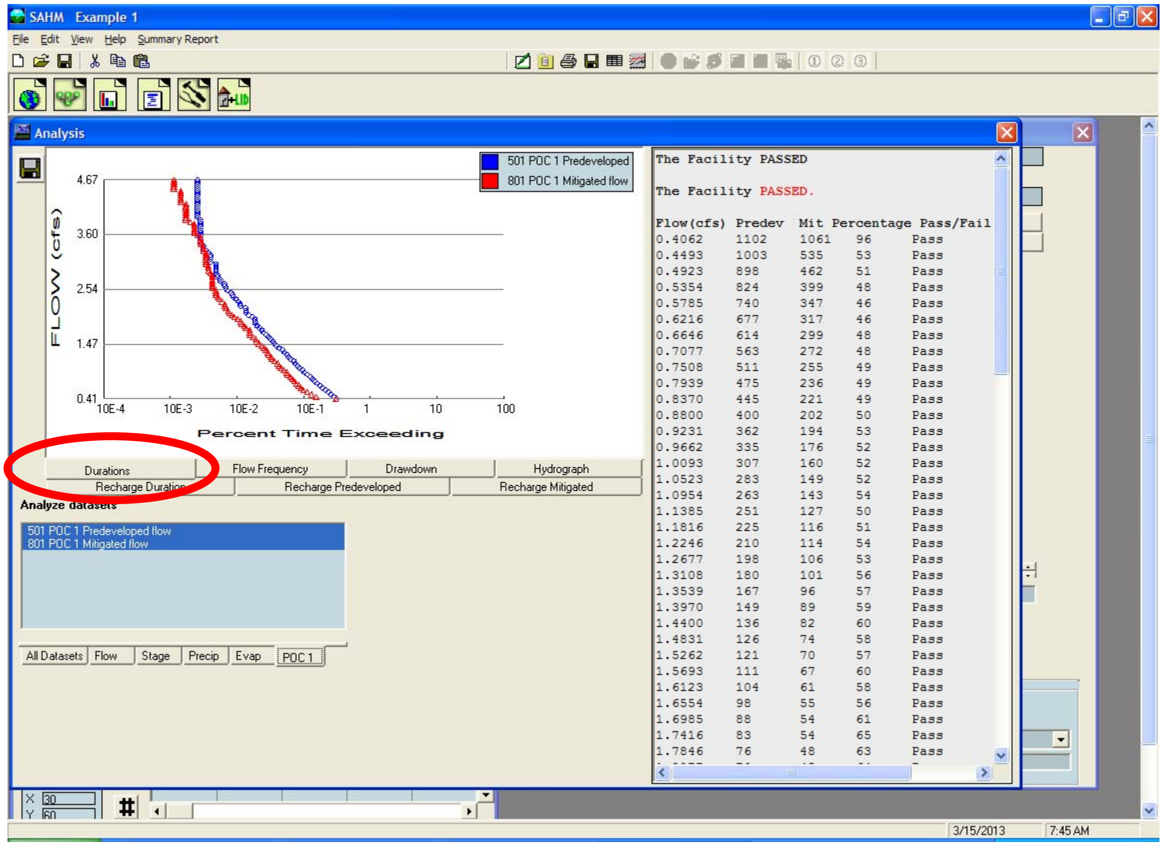
The Analysis tool bar button (third from the left) brings up the Analysis screen where the user can look at the results of the Pre-project and Mitigated scenarios. The Analysis screen allows the user to analyze and compare flow durations, flow frequency, drawdown times, and hydrographs.

The recharge tabs are for the optional analysis of determining Pre-project and Mitigated recharge to the groundwater.



The user can analyze all time series datasets or just flow, stage, precipitation, evaporation, or point of compliance (POC) flows by selecting the appropriate tab below the list of the different datasets available for analysis.

FLOW DURATION



Flow duration at the point of compliance (POC 1) is the most common analysis. A plot of the flow duration values is shown on the left, the flow values on the right.

The flow duration flow range is from the lower threshold flow frequency value (25% of the 2-year value) to the upper threshold flow frequency value (10-year value). As shown in the flow duration table to the right of the flow duration curves, this flow range is divided into approximately 100 levels (flow values).

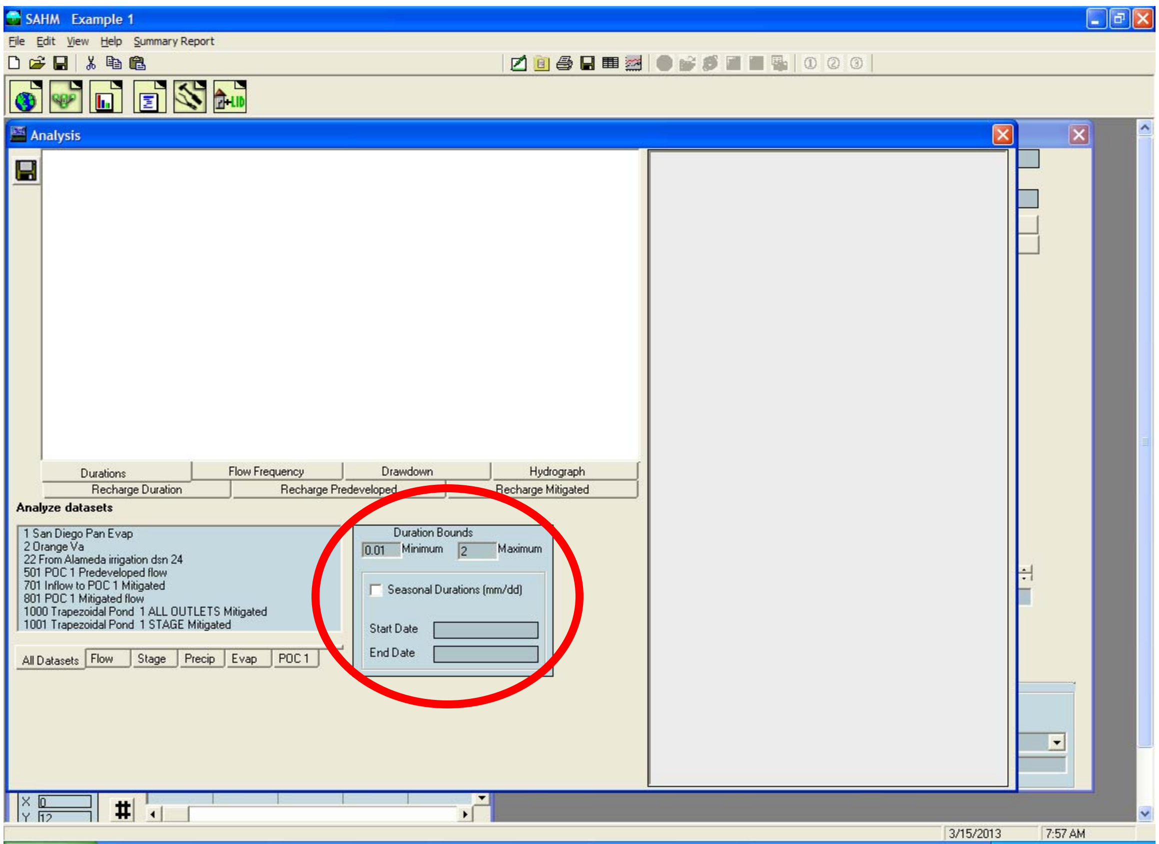
The division of the flow range into a large number of levels is important to make sure that the erosive flows do not increase between the lower threshold (25% of the 2-year flow) and the 2-year flow frequency value and between increasing flow frequency levels (3-year, 4-year, 5-year, etc.). The majority of the erosive flows occur between the 25% of the 2-year flow value and the 2-year flow frequency value. It is important to divide the flow levels in that range into multiple level steps to not miss any occasions when the mitigated flows exceed the pre-project flows.

For each flow level/value SAHM counts the number of times that the flow at the Point of Compliance for the Pre-project scenario (Predev) exceeds that specific flow level/value.

It does the same count for the Mitigated scenario flow (Mit). The total number of counts is the number of simulated hours that the flow exceeds that specific flow level/value.

The Percentage column is the ratio of the Dev count to the Predev count. This ratio must be less than or equal to 110% for flow levels/values between the lower threshold (25% of the 2-year flow) and upper threshold (10-year flow). Only a maximum of 10 of the 100 flow levels/values may exceed 100%; all other flow levels/values must be 100% or less.

If the percentage value does not exceed these rules then the Pass/Fail column shows a Pass for that flow level. If they are exceeded then a Fail is shown. A single Fail and the facility fails the flow duration criteria. The facility overall Pass/Fail is listed at the top of the flow duration table.

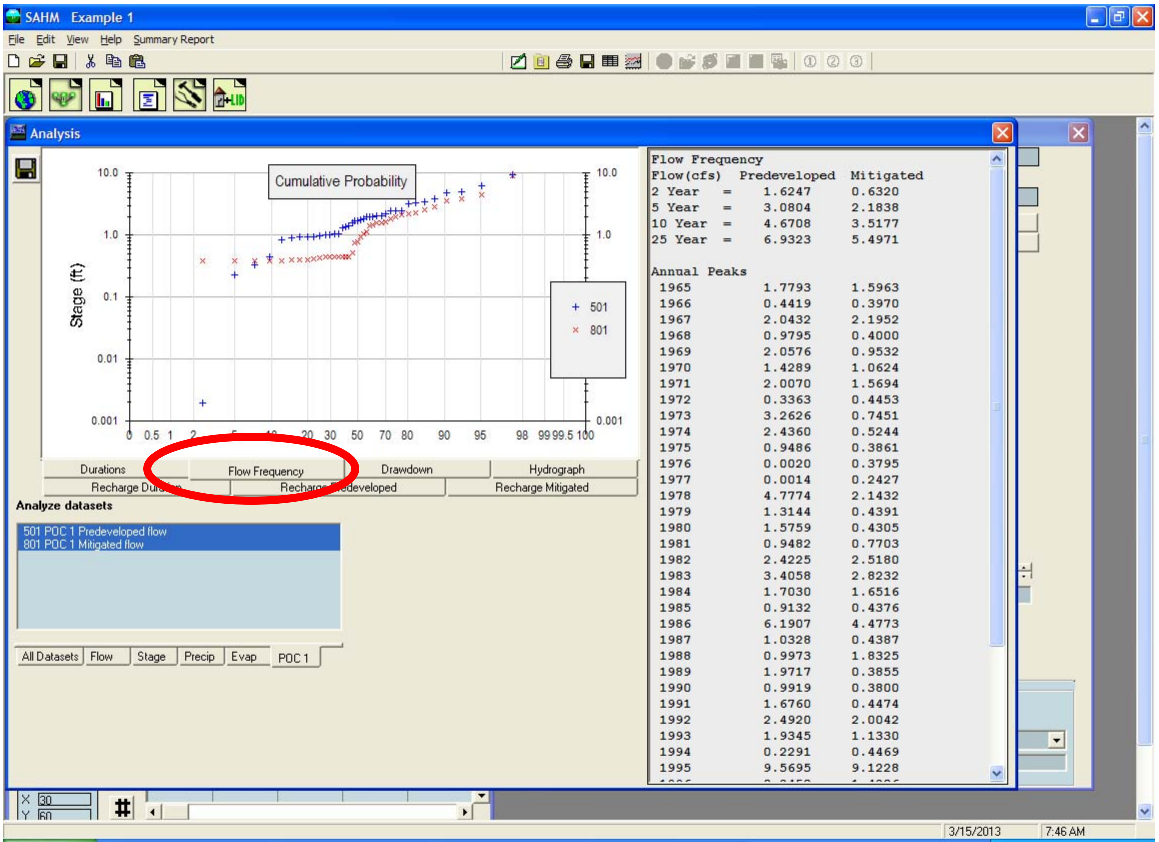


The user also has the option of computing a duration curve for any of the data sets listed with user-defined lower and upper limits. The default minimum and maximum duration bounds are 0.01 and 2.0, but these can be changed by the user to any appropriate values (for example, the minimum can be changed to zero).

Duration analysis is done for the entire 12 months of every year in the modeling period of record. However, if the user wants to compute the durations for only a portion of a year the Seasonal Duration option can be used. The user inputs a start date (mm/dd) and an end date (mm/dd). For example, if the user is interested in a duration analysis of only summer flows the start date can be set to 06/21 and the end date input as 09/22. Then,

using the user-defined minimum and maximum duration bounds, SAHM will compute the duration analysis for that summer season.

FLOW FREQUENCY



Flow frequency plots are shown on the left and the 2-, 5-, 10-, and 25-year frequency values are on the right. Flow frequency calculations are based on selecting annual flow values and ranking them by their Weibull Plotting Position.

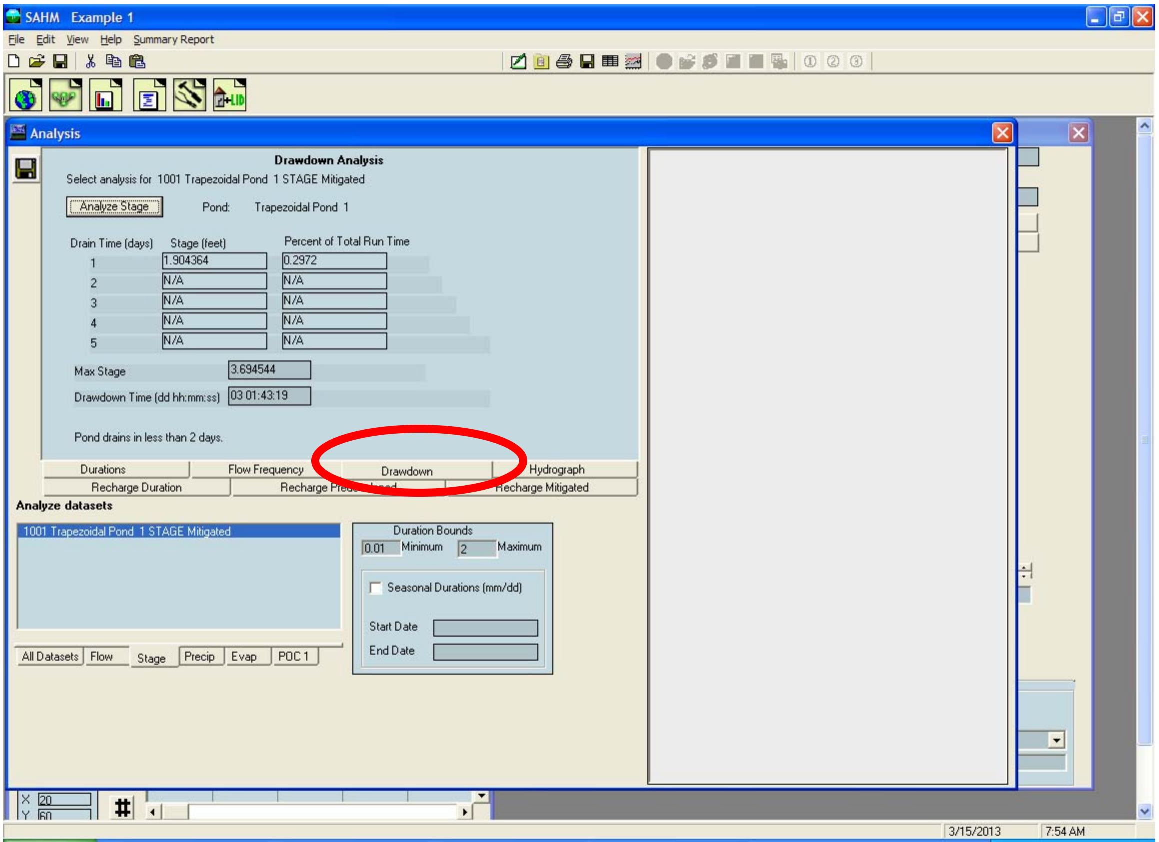
The Weibull Plotting Position formula is:

Tr = (N+a)/(m-b) where Tr = return period (years)
m = rank (largest event, m = 1)
N = number of years
a = 1
b = 0

Probability = 1/Tr

The return period value, Tr, is used in SAHM to determine the 2-year, 5-year, 10-year, and 25-year peak flow values. If necessary, the 2-year, 5-year, 10-year, and 25-year values are interpolated from the Tr values generated by Weibull.

DRAWDOWN



The drawdown screen is used to compute pond stages (water depths). These stages are summarized and reported in terms of drain/retention time (in days).

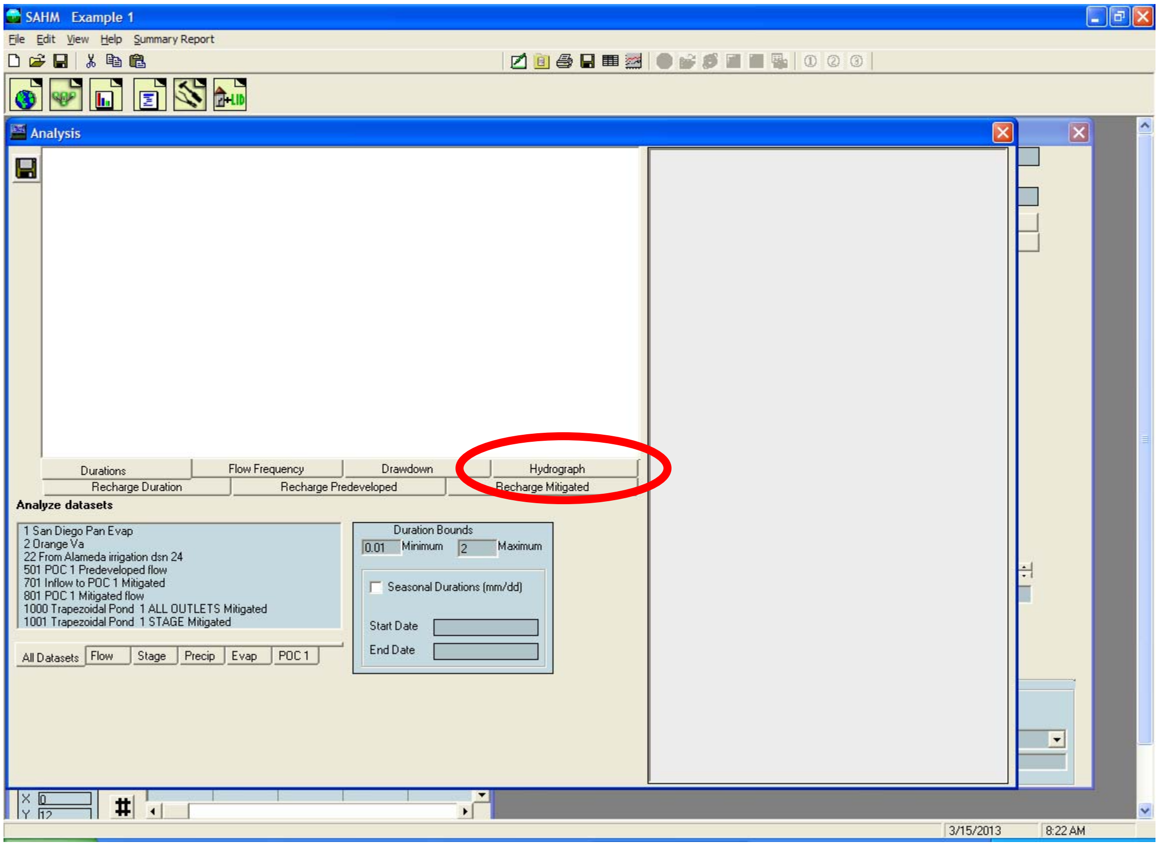
For this example, the maximum stage computed during the entire 30-50 year simulation period is 3.69 feet. This maximum stage has a drawdown time of 3 days, 1 hour, 43 minutes, 19 seconds (approximately 74 hours).

The 1-day (24-hour) drain time is needed to drain the pond when it is at a stage of 1.90 feet. This stage occurs 0.29% of the total simulation time.

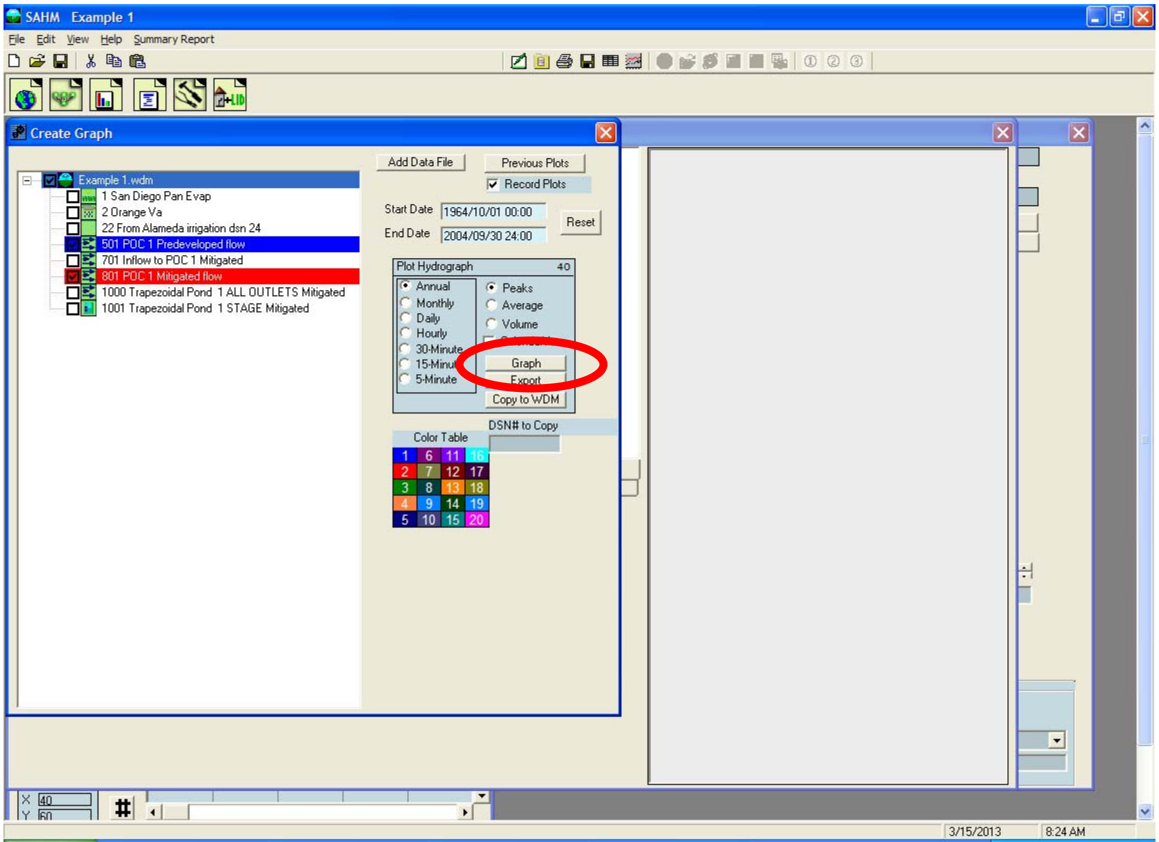
Ponds may have drain times in excess of the allowed maximum. This can occur when a pond has a small bottom orifice. If this is not acceptable then the user needs to change the pond outlet configuration, manually run the Mitigated scenario, and repeat the analyze stage computations. A situation may occur where it is not possible to have both an acceptable pond drawdown/ retention time and meet the flow duration criteria.

NOTE: The flow duration criteria take precedence unless the user is instructed otherwise by Appendix C or the local municipal permitting agency.

HYDROGRAPHS



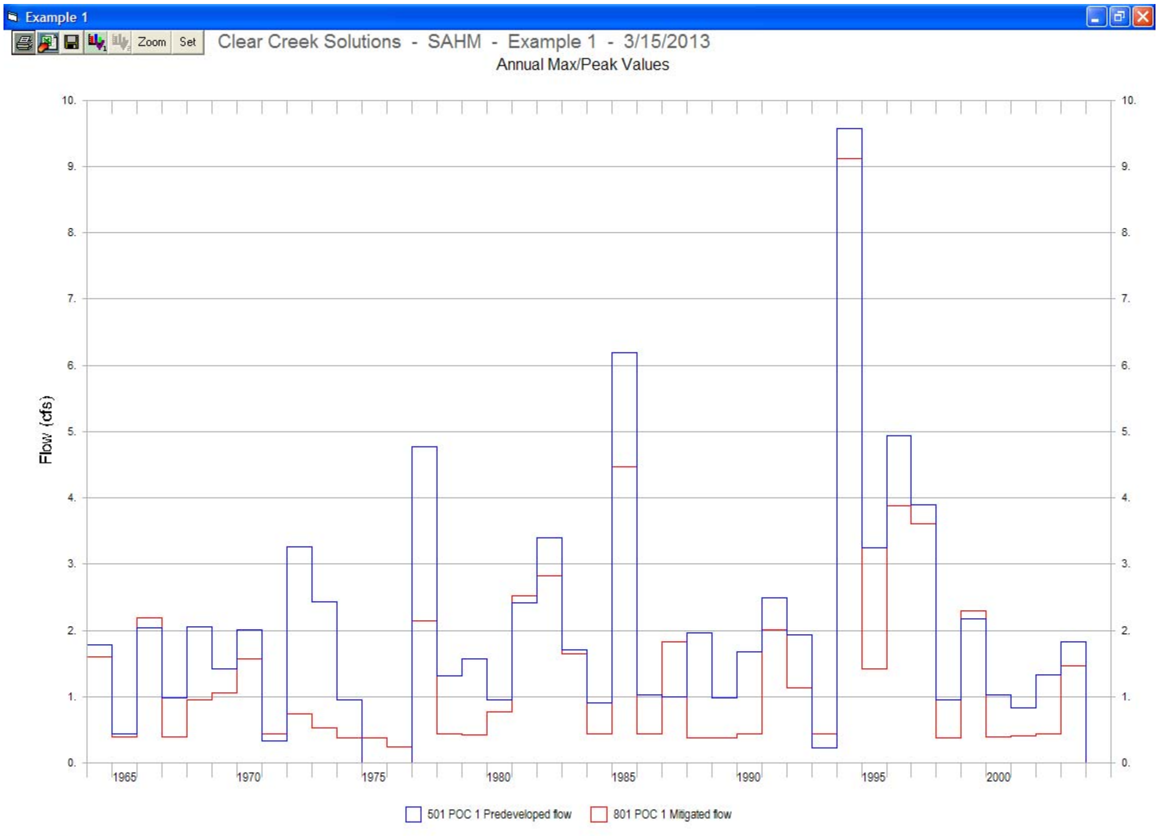
The user can graph/plot any or all time series data by selecting the Hydrograph tab.



The Create Graph screen is shown and the user can select the time series to plot, the time interval (yearly, monthly, daily, or hourly), and type of data (peaks, average, or volume).

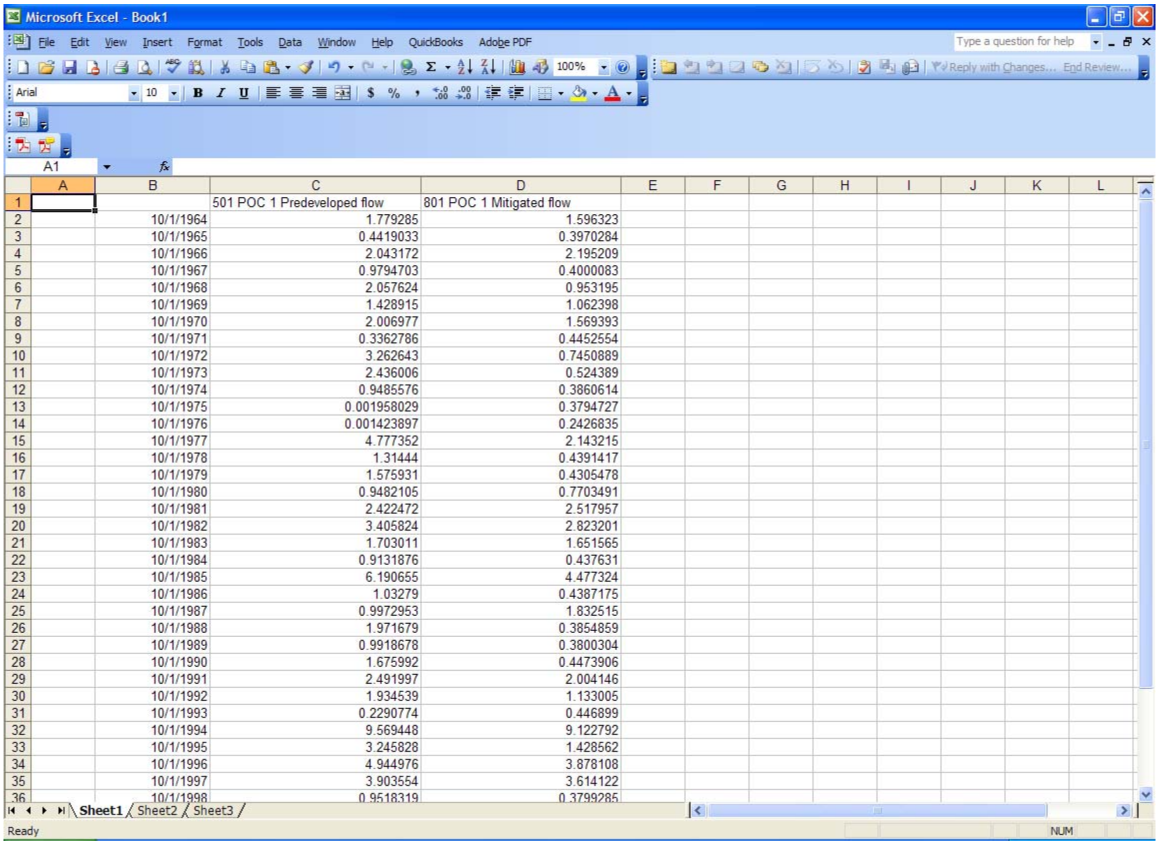
The following numbering system is used for the flow time series:
500-599: Pre-project flow (Pre-project scenario)
700-799: Inflow to the POC (Mitigated runoff entering the BMP facility)
800-899: POC flow (Mitigated flow exiting the BMP facility)

The selected time series are shown in color. To graph the selected time series the user clicks on the Graph button.



In this example the hydrograph shows the yearly maximum/peak flow values for each time series for the entire simulation period from 1964 through 2004.

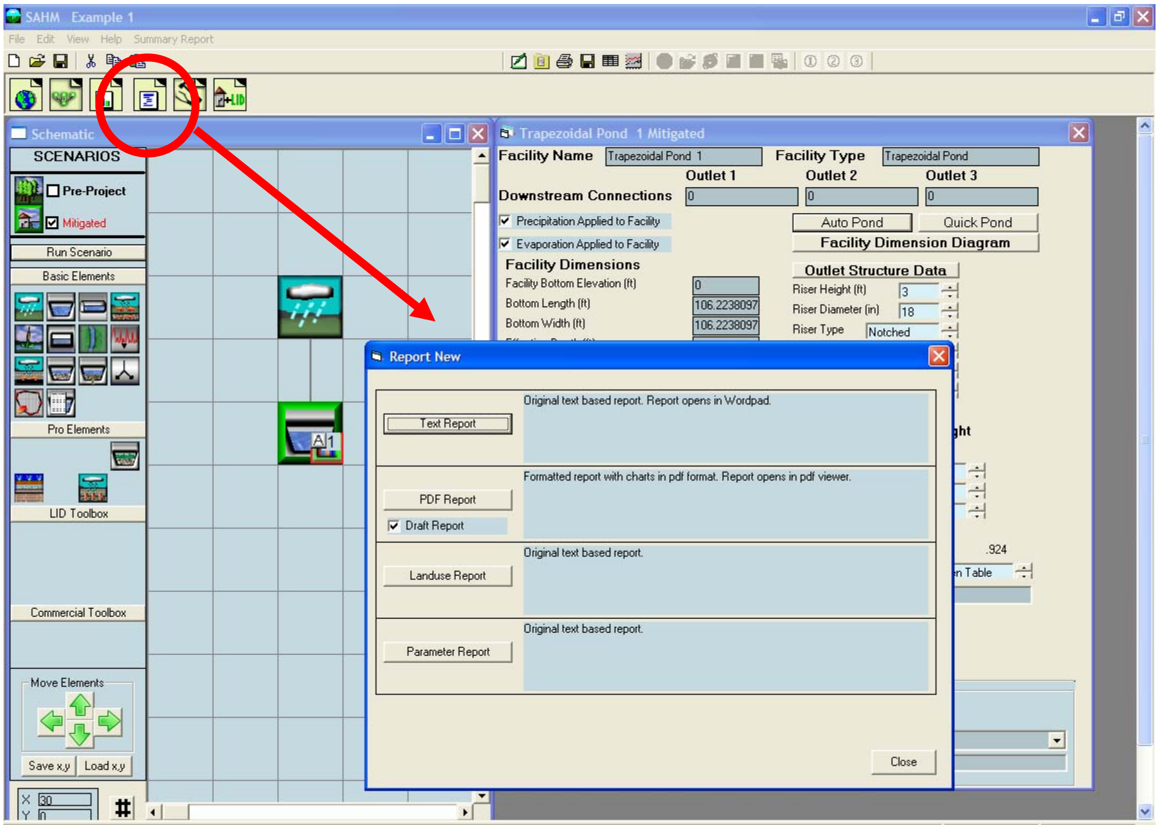
The graph can be saved, copied to Windows Clipboard, or printed.



	B	C	D
1		501 POC 1 Predeveloped flow	801 POC 1 Mitigated flow
2	10/1/1964	1.779285	1.596323
3	10/1/1965	0.4419033	0.3970284
4	10/1/1966	2.043172	2.195209
5	10/1/1967	0.9794703	0.4000083
6	10/1/1968	2.057624	0.953195
7	10/1/1969	1.428915	1.062398
8	10/1/1970	2.006977	1.569393
9	10/1/1971	0.3362786	0.4452554
10	10/1/1972	3.262643	0.7450889
11	10/1/1973	2.436006	0.524389
12	10/1/1974	0.9485576	0.3860614
13	10/1/1975	0.001958029	0.3794727
14	10/1/1976	0.001423897	0.2426835
15	10/1/1977	4.777352	2.143215
16	10/1/1978	1.31444	0.4391417
17	10/1/1979	1.575931	0.4305478
18	10/1/1980	0.9482105	0.7703491
19	10/1/1981	2.422472	2.517957
20	10/1/1982	3.405824	2.823201
21	10/1/1983	1.703011	1.651565
22	10/1/1984	0.9131876	0.437631
23	10/1/1985	6.190655	4.477324
24	10/1/1986	1.03279	0.4387175
25	10/1/1987	0.9972953	1.832515
26	10/1/1988	1.971679	0.3854859
27	10/1/1989	0.9918678	0.3800304
28	10/1/1990	1.675992	0.4473906
29	10/1/1991	2.491997	2.004146
30	10/1/1992	1.934539	1.133005
31	10/1/1993	0.2290774	0.446899
32	10/1/1994	9.569448	9.122792
33	10/1/1995	3.245828	1.428562
34	10/1/1996	4.944976	3.878108
35	10/1/1997	3.903554	3.614122
36	10/1/1998	0.9518319	0.3799285

Graphs that are copied to Windows Clipboard can then be pasted into a Microsoft Excel spreadsheet with the individual plotted values shown in the spreadsheet.

REPORTS SCREEN



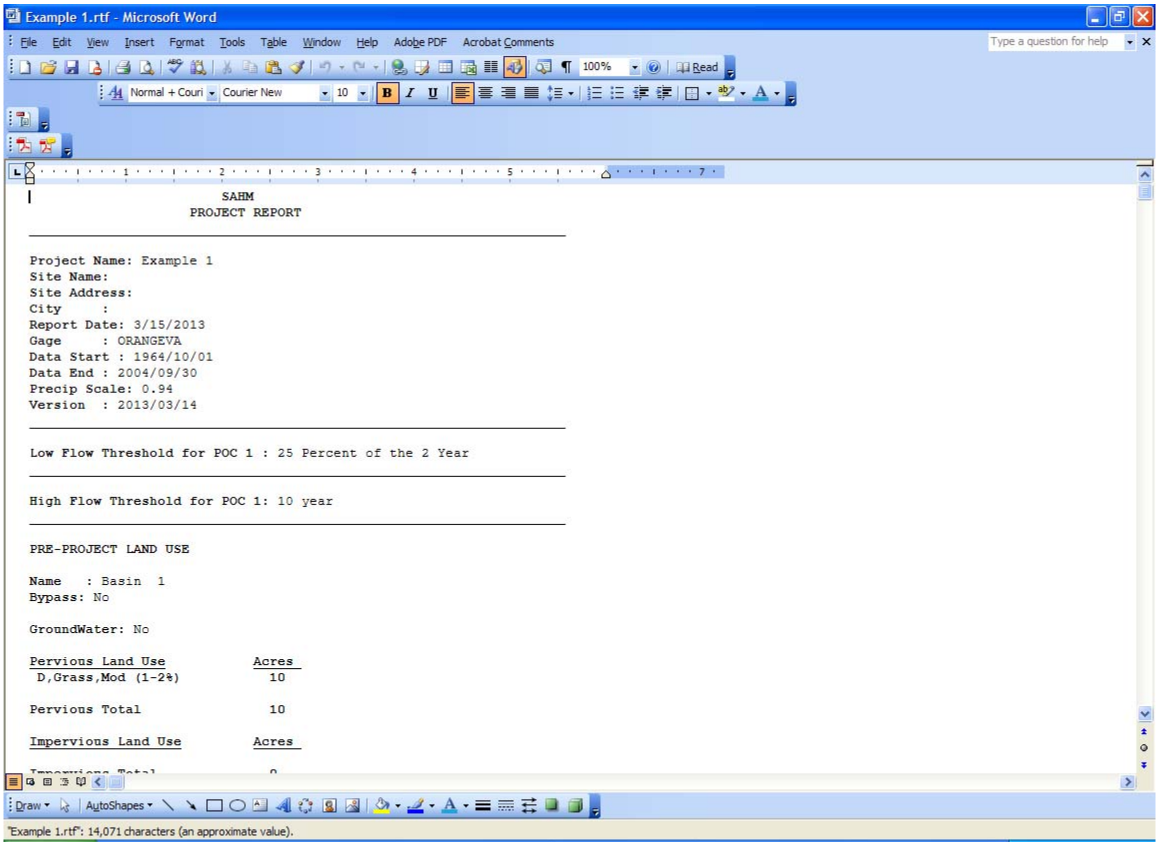
Click on the Reports tool bar button (fourth from the left) to select the Report options table.

Selecting Text Report will generate a project report in Microsoft Word RTF format with all of the project information and results.

Selecting PDF Report will generate a project report in Adobe Acrobat PDF format with all of the project information and results.

The Landuse Report produces a list of the land use information contained in the project.

The Parameter Report lists any HSPF parameter value changes made by the user.



SAHM
PROJECT REPORT

Project Name: Example 1
Site Name:
Site Address:
City :
Report Date: 3/15/2013
Gage : ORANGEVA
Data Start : 1964/10/01
Data End : 2004/09/30
Precip Scale: 0.94
Version : 2013/03/14

Low Flow Threshold for POC 1 : 25 Percent of the 2 Year

High Flow Threshold for POC 1: 10 year

PRE-PROJECT LAND USE

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	Acres
D,Grass,Mod (1-2%)	10
Pervious Total	10

Impervious Land Use	Acres

Scroll down the Text Report or the PDF Report screen to see all of the results.

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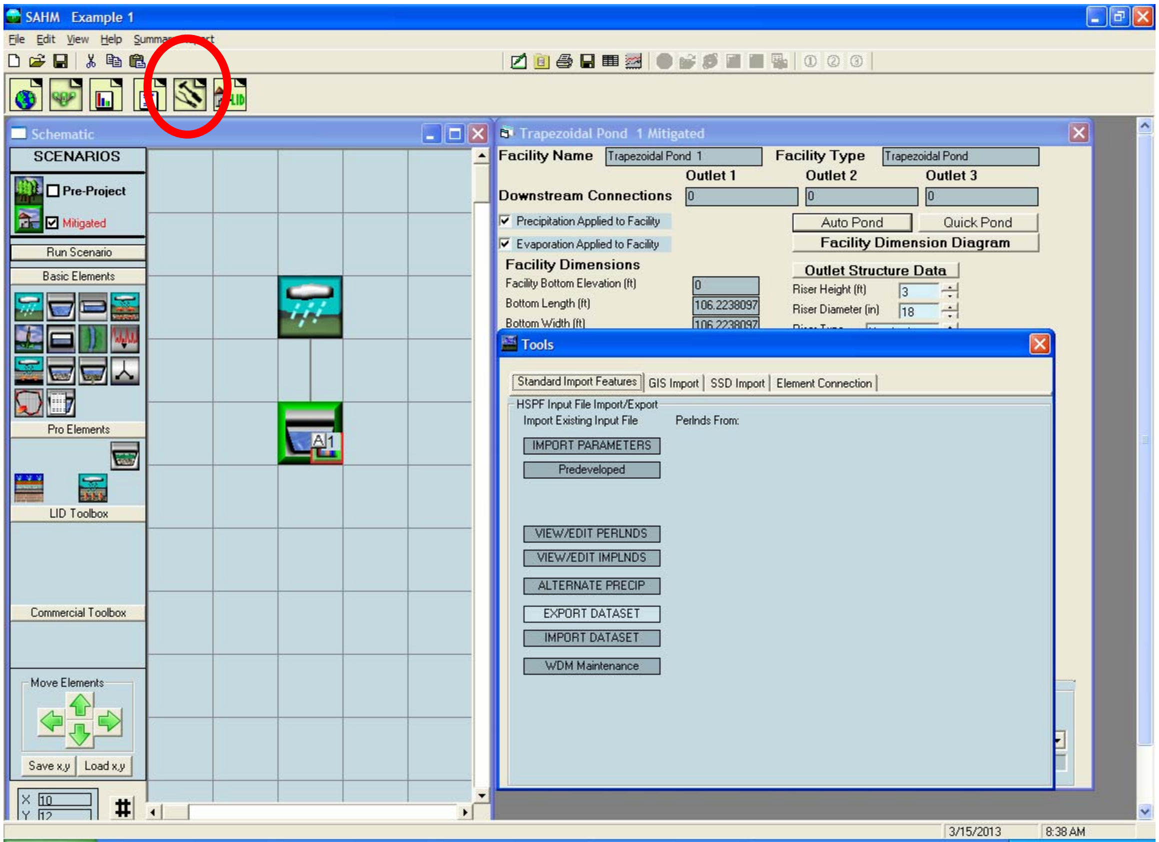
TOOLS SCREEN

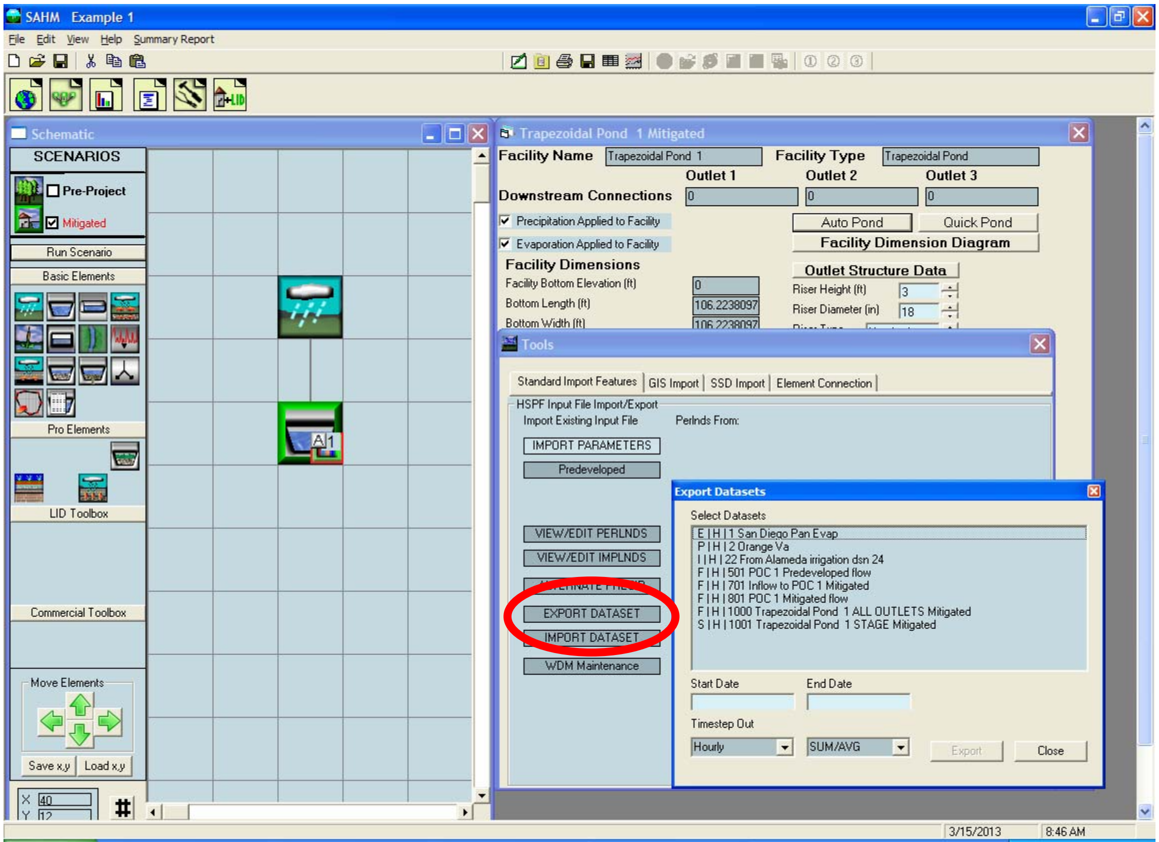


The Tools screen is accessed with the Tools tool bar (second from the right). The two major purposes of the Tools screen are:

(1) To allow users to view SAHM HSPF PERLND parameter values. The parameter values are locked and cannot be changed by the user.

(2) To allow users to export time series datasets.

To export a time series dataset click on the Export Dataset box.



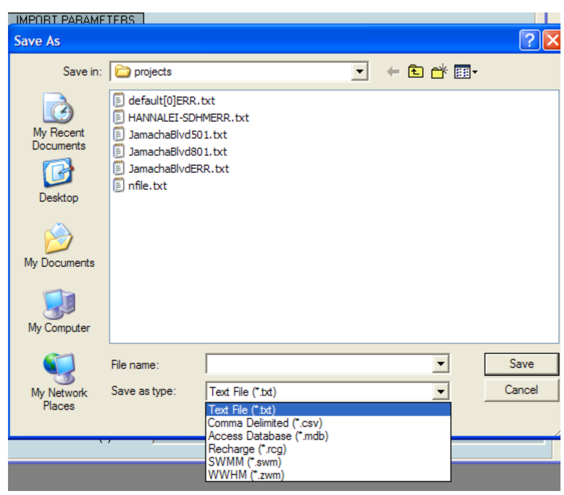
The list of available time series datasets will be shown. The user can select the start and end dates for the data they want to export.

The time step (hourly, daily, monthly, yearly) can also be specified. If the user wants daily, monthly, or yearly data the user is given the choice of either selecting the maximum, minimum, or the sum of the hourly values.

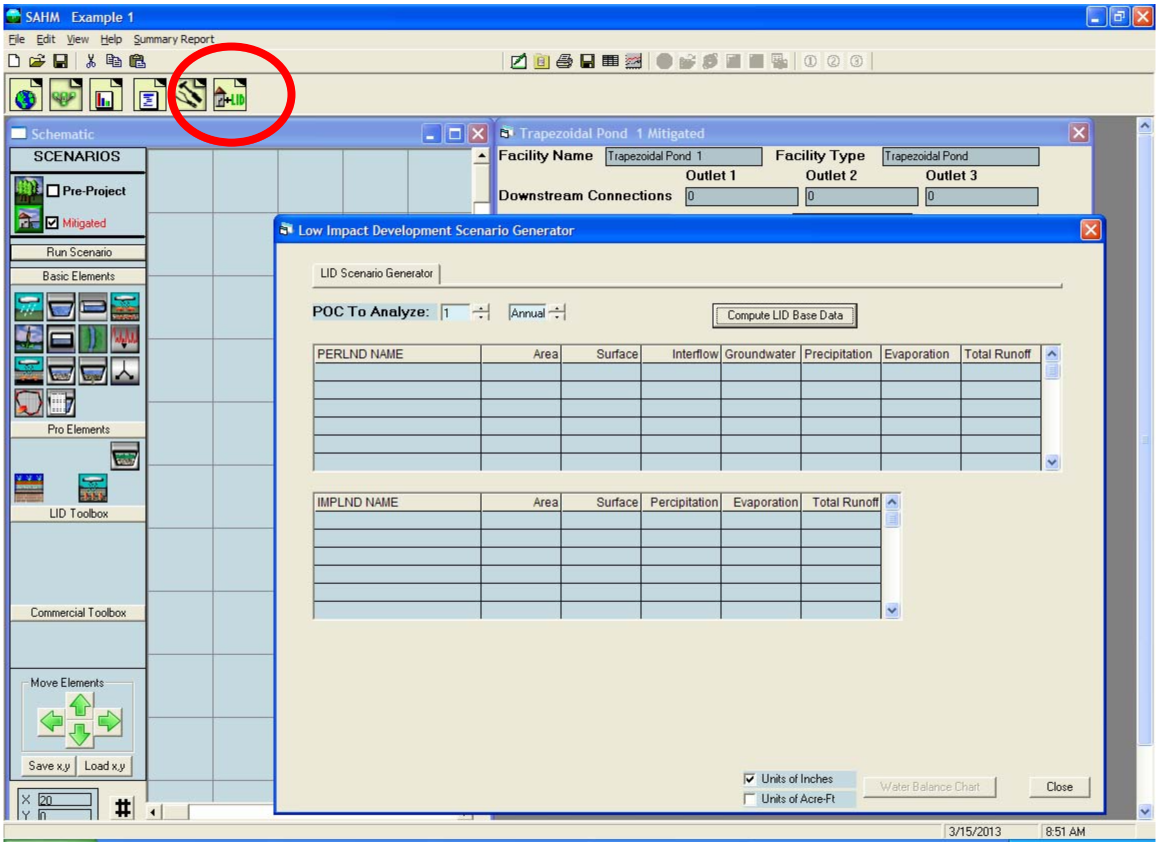
Click the Export button.

The user provides a file name and the format or type of file. The file type can be ASCII text, comma delimited, Access database, recharge, SWMM, or WWHM.

Click Save to save the exported time series file.



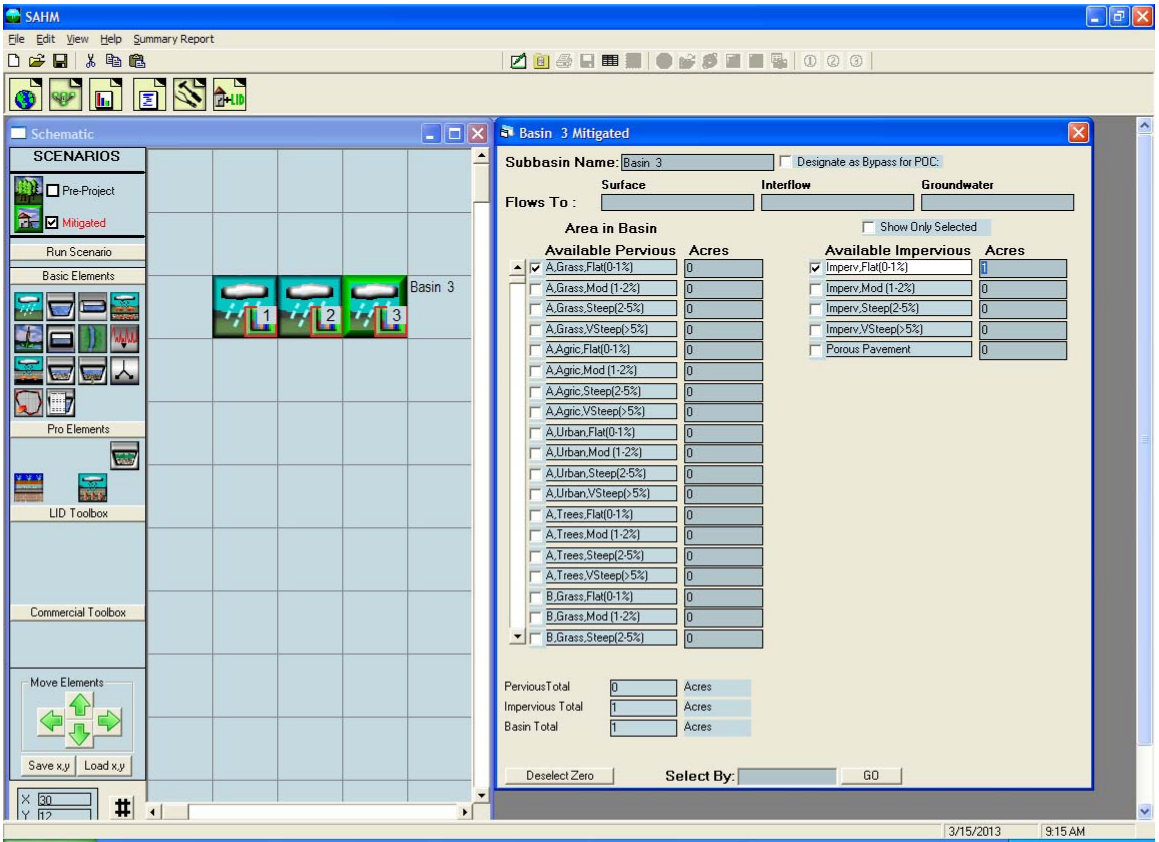
LID ANALYSIS SCREEN



The LID tool bar button (farthest on the right) brings up the Low Impact Development Scenario Generator screen.

The LID scenario generator can be used to compare the amount of runoff from different land types and combinations. By clicking on the Compute LID Base Data the user can quickly see how changing the land use affects surface runoff, interflow, groundwater, and evapotranspiration.

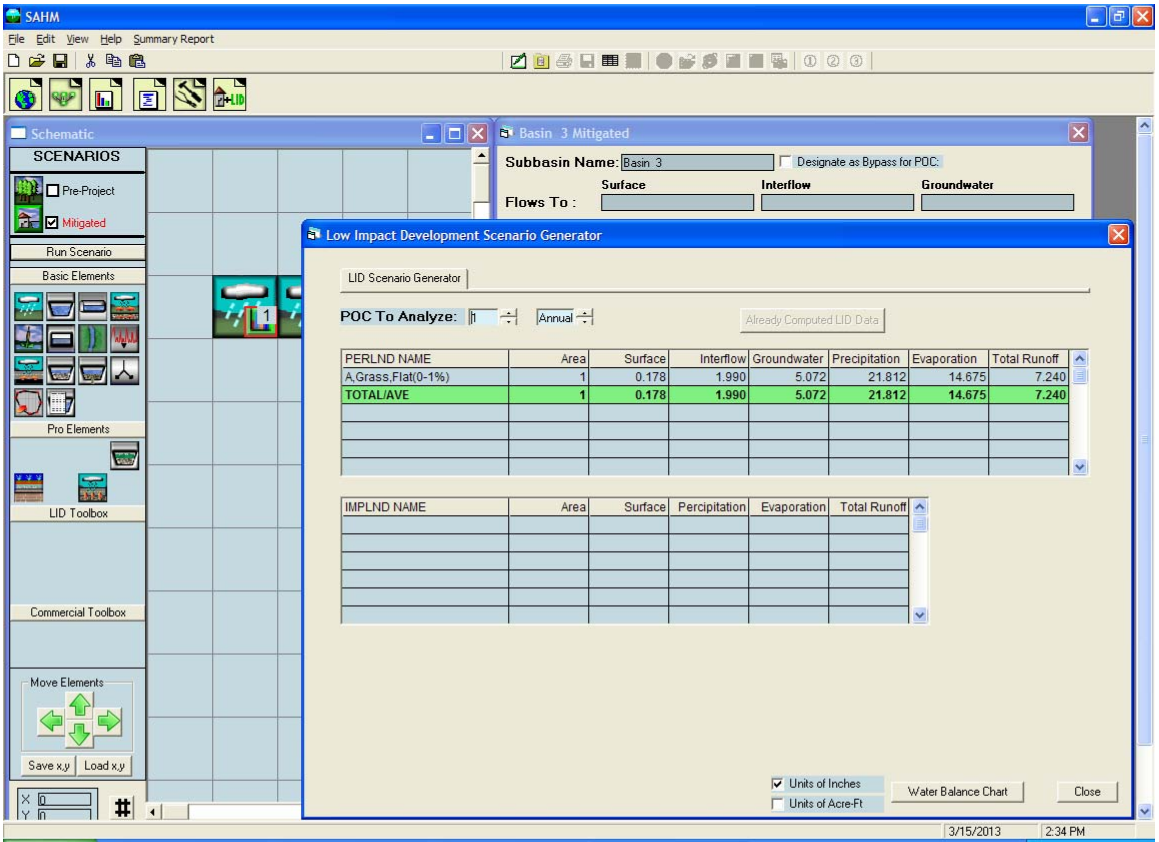
NOTE: The LID scenario generator works only in the Mitigated scenario.



The easiest way to compare different land use scenarios is to place all of them on the same Schematic Editor screen grid in the Mitigated scenario. Each basin can then represent a different land use scenario. Because the LID scenario generator only compares runoff volume there is no need to do any routing through a conveyance system or stormwater facility.

For this example the three basins are assigned the following land uses:
Basin 1: 1 acre A, Grass, Flat
Basin 2: 1 acre D, Agriculture, Moderate
Basin 3: 1 acre Impervious, Flat

The user should assign a different POC (point of compliance) to each basin for the LID analysis.



Click on the Compute LID Base Data button to generate the LID analysis data and summarize the surface runoff, interflow, groundwater, precipitation, evaporation, and total runoff for all of the basins. The results will be shown for each basin in terms of its POC.

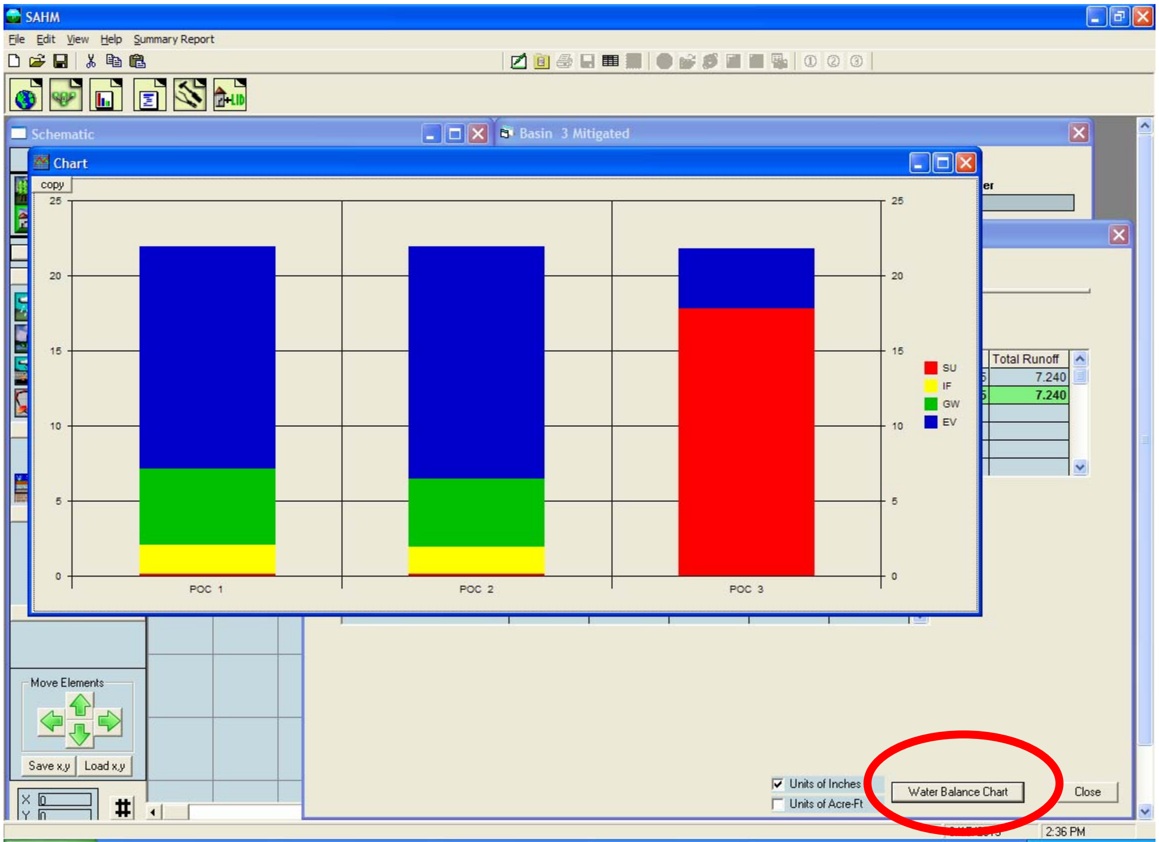
For Basin 1 (1 acre of A, Grass, Flat) the distribution of the precipitation is:
Surface runoff = 0.178 inches per year
Interflow = 1.990 inches per year
Groundwater = 5.072 inches per year
Evaporation = 14.675 inches per year

The sum of the surface runoff + interflow + active groundwater + evaporation equals 21.91 inches per year. The precipitation at this site equals 21.81 inches per year. The difference is due to the depletion of the initial groundwater storage.

To look at the other basins click on the Select POC To arrow and select the basin of interest.

The LID analysis results can be presented in terms of either inches per year or acre-feet per year by checking the appropriate box in the lower right portion of the LID analysis screen.

To compare the different scenarios side-by-side in a graphical format click on the Display Water Balance Chart.

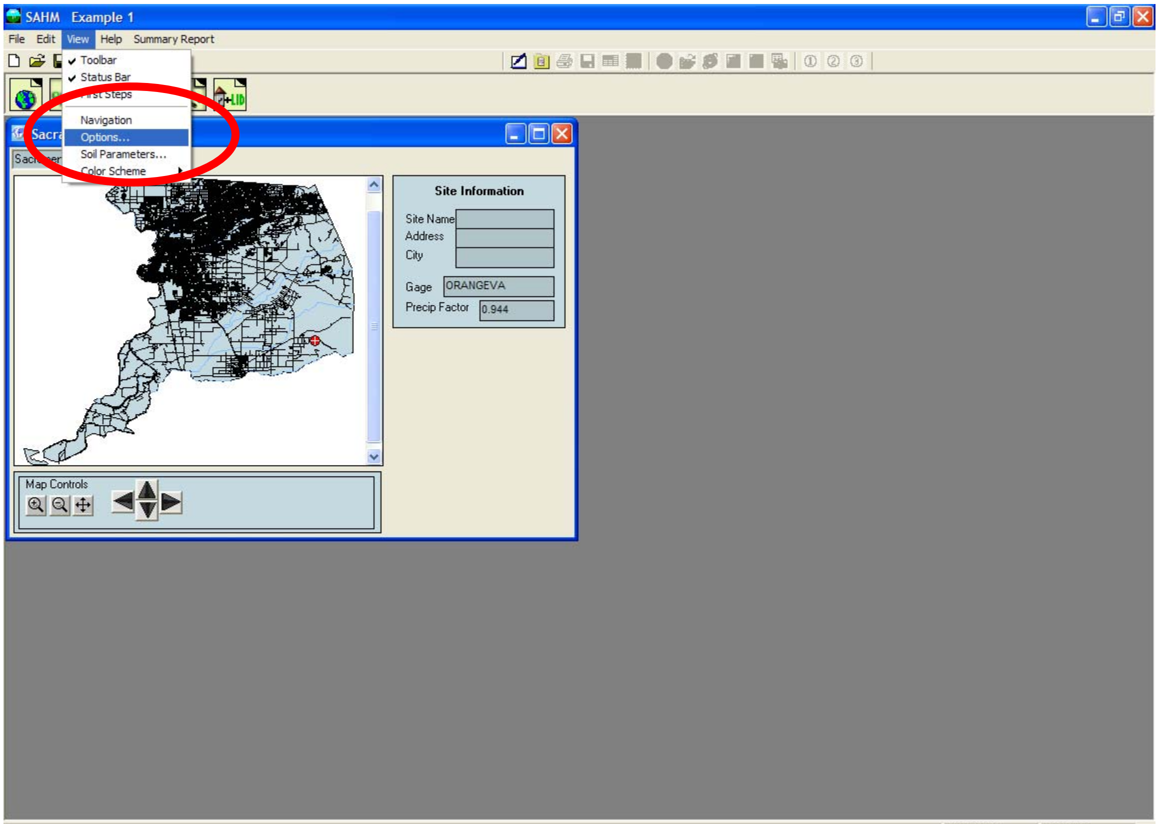


The water balance chart graphically displays the runoff distribution for all three land use scenarios side-by-side.

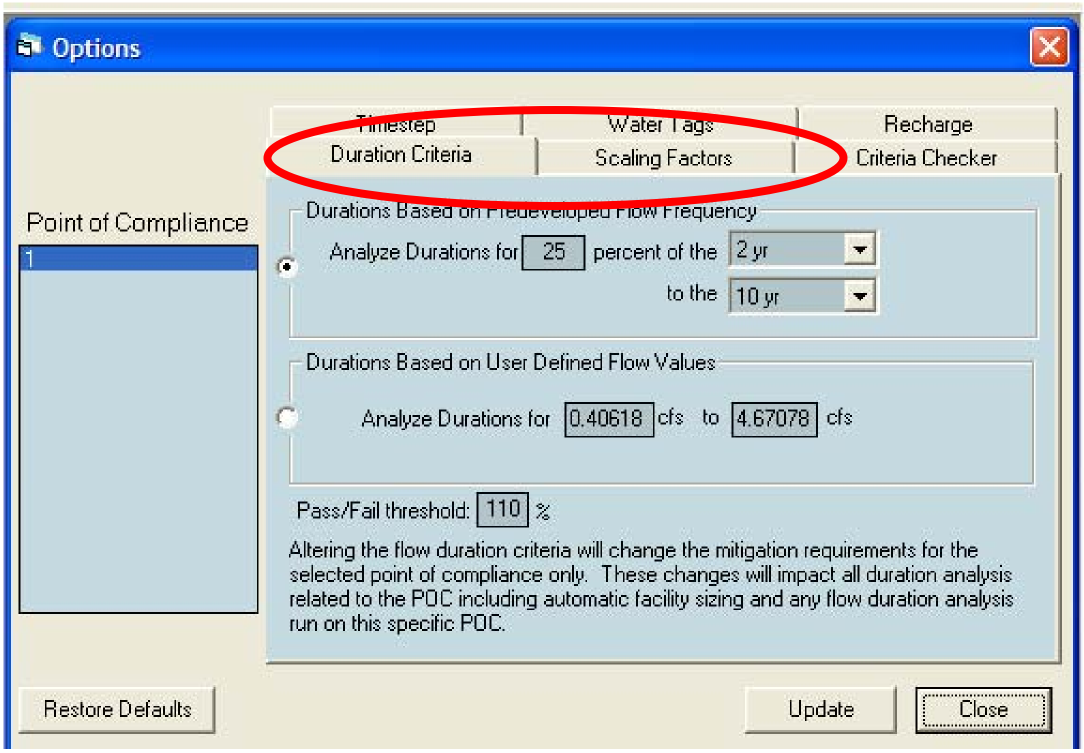
The bottom red is the surface runoff. Above in yellow is interflow; then green for groundwater and blue for evaporation. Basin 1 (Scenario 1) is an A soil with grass land cover on a flat slope and produces the least amount of surface runoff and interflow (the sum of surface and interflow is the total stormwater runoff). Basin 2 is a D soil with agriculture land cover on a moderate slope; it produces more surface runoff and interflow than Basin 1. Basin 3 is impervious and produces the largest amount of surface runoff and the smallest amount of evaporation.

A maximum of seven scenarios can be graphed at one time.

OPTIONS

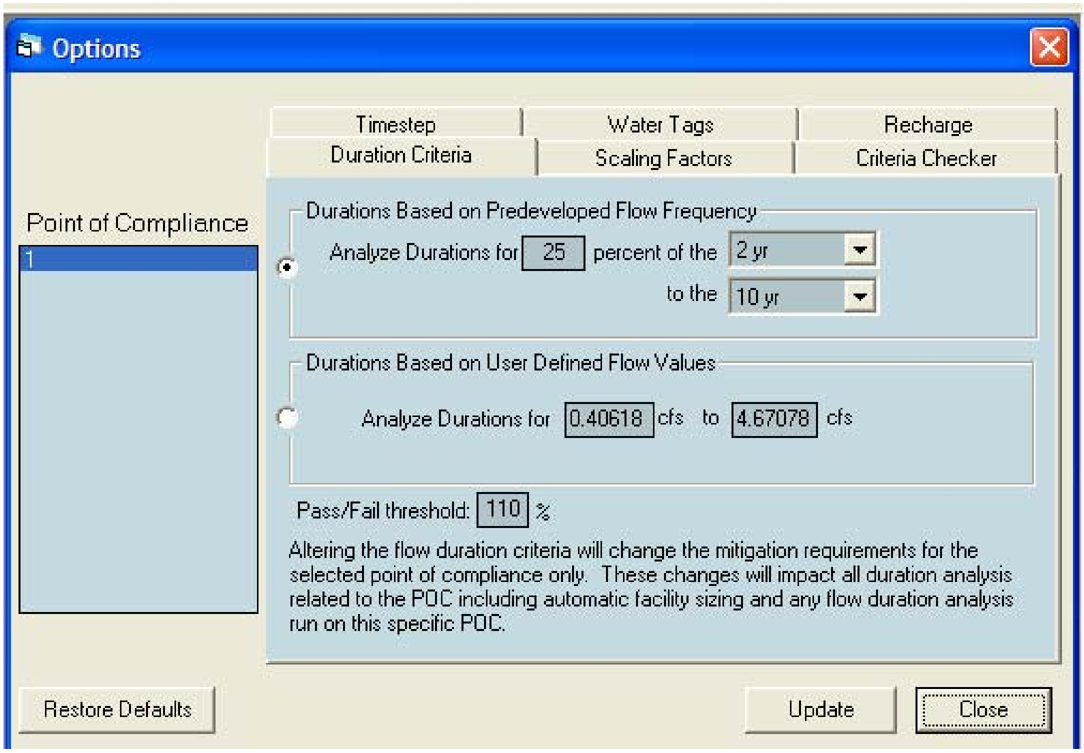


Options can be accessed by going to View, Options.



This will bring up the Options screen and the ability to modify the built-in default duration criteria for flow duration matching and scaling factors for climate variables.

DURATION CRITERIA



The flow duration criteria are:

1. If the post-development flow duration values exceed any of the pre-project flow levels between the lower threshold (25% of the two-year) and the upper threshold (100% of the ten-year) pre-project peak flow values more than 10 percent of the time (110 Percent Threshold) then the flow duration standard has not been met.

2. If more than 10 percent of the flow duration levels exceed the 100 percent threshold then the flow duration standard has not been met.

The duration criteria in SAHM can be modified by the user if appropriate and the local municipal permitting agency allows (see NOTE below).

The user can conduct the duration analysis using either (1) durations based on Pre-project flow frequency, or (2) durations based on user defined flow values.

If using durations based on Pre-project flow frequency, the percent of the lower limit can be changed from the default of the 25% of the 2-year flow event to 45%, where appropriate.

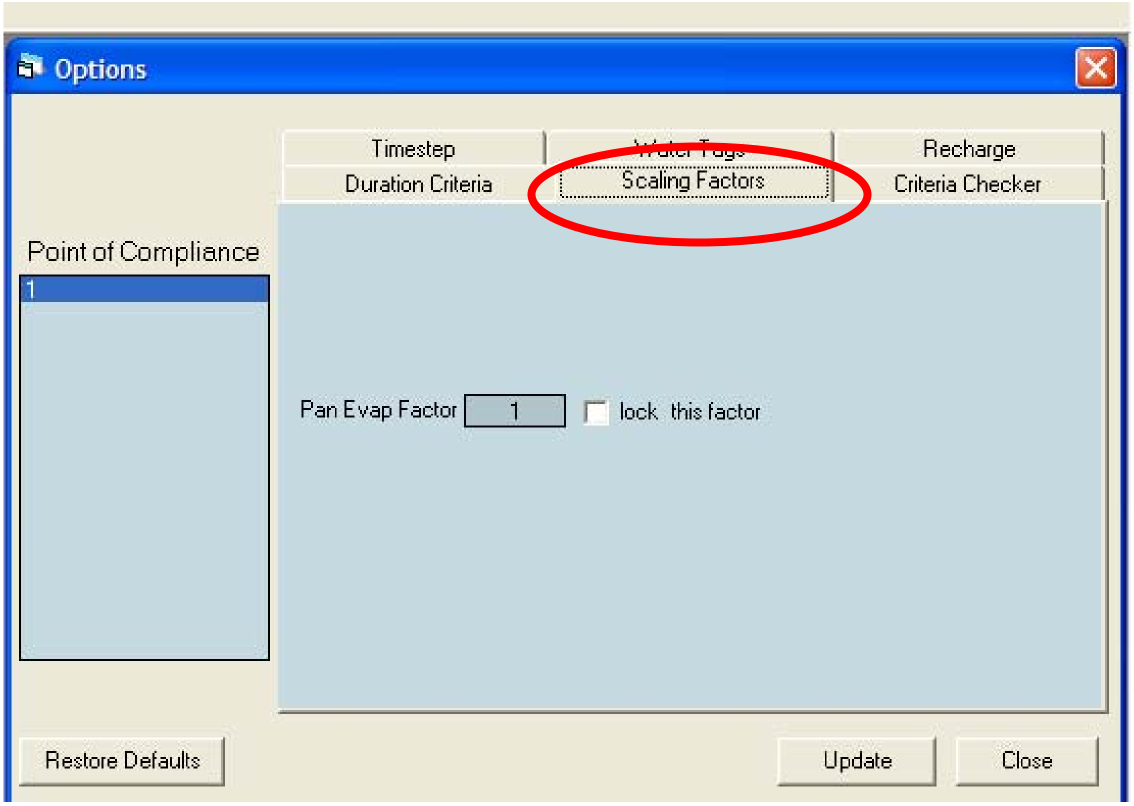
If using durations based on user defined flow values, click on that option and input the lower and upper flow values.

The default pass/fail threshold is 110% for the flows between the lower threshold (25% of the 2-year) and the upper threshold (10-year flow).

The duration criteria can be changed for a single point of compliance. Click on the Update button once all of the changes have been made. To return to the default values click on the Restore Defaults button.

NOTE: Any change(s) to the default duration criteria must be approved by the appropriate local municipal permitting agency or specified in Appendix C.

SCALING FACTORS



The user has the ability to change the scaling factor for pan evaporation. The default value is 1.00.

NOTE: Any change in default scaling factors requires approval by the local municipal permitting agency or Appendix C.

Click on the Update button once all of the changes have been made. To return to the default values click on the Restore Defaults button.

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TIPS AND TRICKS FOR LID PRACTICES AND FACILITIES

There are many different tips and tricks that can be used to tailor SAHM to solve different stormwater problems. This section presents only a fraction of the tricks that we and others have found and used, but it should give you a good idea of the options and flexibility built into SAHM.

The tips and tricks show how different water quality treatment control facilities can be represented by SAHM elements.

Specific treatment control facilities from the 2007 *Stormwater Quality Design Manual* are listed in Table 1 along with the appropriate SAHM model element. As of March 2013, the design manual is being revised and updated by RBF Consulting. Once a new manual is published this section will be revised to be consistent with the new manual.

Table 1. Treatment Control Facilities and Equivalent SAHM Elements

Treatment Control Facility	**SAHM Model Element**
Constructed wetland basin	Trapezoidal pond or Irregular-shaped pond or SSD Table
Water quality detention basin	Trapezoidal pond or Irregular-shaped pond or SSD Table
Infiltration basin	Trapezoidal pond or Irregular-shaped pond with infiltration turned on
Infiltration trench	Gravel trench/bed
Sand filter	Sand filter
Stormwater planter	Bioretention or planter box
Vegetated swale	Bioretention swale or natural channel or vegetated swale
Vegetated filter strip	Bioretention swale or lateral flow impervious area + lateral flow soil basin

NOTE: Many of these treatment control facilities rely on infiltration into native soils. See Appendix C or consult with the local municipal permitting agency for additional considerations regarding infiltration and determination of an infiltration reduction factor, where appropriate.

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APPENDIX A: DEFAULT SAHM HSPF PERVIOUS PARAMETER VALUES

The default SAHM HSPF pervious parameter values are found in SAHM file defaultpers.uci.

HSPF parameter values in SAHM have been adjusted for the different soil, land cover, and land slope categories of Sacramento County based on the professional judgment and experience of Clear Creek Solutions HSPF modelers in northern California.

HSPF parameter documentation is found in the document:
Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, T.H. Jobes, and A.S. Donigian Jr. 2001. Hydrological Simulation Program – Fortran, User's Manual for Version 12. AQUA TERRA Consultants. Mountain View, CA.

Table 1. SAHM Pervious Land Types

PERLND No.	Soil Type	Land Cover	Land Slope
1	A	Grass	Flat (0-1%)
2	A	Grass	Moderate (1-2%)
3	A	Grass	Steep (2-5%)
4	A	Grass	Very Steep (>5%)
5	A	Agricultural	Flat (0-1%)
6	A	Agricultural	Moderate (1-2%)
7	A	Agricultural	Steep (2-5%)
8	A	Agricultural	Very Steep (>5%)
9	A	Urban	Flat (0-1%)
10	A	Urban	Moderate (1-2%)
11	A	Urban	Steep (2-5%)
12	A	Urban	Very Steep (>5%)
13	A	Trees	Flat (0-1%)
14	A	Trees	Moderate (1-2%)
15	A	Trees	Steep (2-5%)
16	A	Trees	Very Steep (>5%)
17	B	Grass	Flat (0-1%)
18	B	Grass	Moderate (1-2%)
19	B	Grass	Steep (2-5%)
20	B	Grass	Very Steep (>5%)
21	B	Agricultural	Flat (0-1%)
22	B	Agricultural	Moderate (1-2%)
23	B	Agricultural	Steep (2-5%)
24	B	Agricultural	Very Steep (>5%)
25	B	Urban	Flat (0-1%)
26	B	Urban	Moderate (1-2%)
27	B	Urban	Steep (2-5%)
28	B	Urban	Very Steep (>5%)
29	B	Trees	Flat (0-1%)
30	B	Trees	Moderate (1-2%)
31	B	Trees	Steep (2-5%)
32	B	Trees	Very Steep (>5%)
33	C	Grass	Flat (0-1%)
34	C	Grass	Moderate (1-2%)
35	C	Grass	Steep (2-5%)
36	C	Grass	Very Steep (>5%)
37	C	Agricultural	Flat (0-1%)
38	C	Agricultural	Moderate (1-2%)
39	C	Agricultural	Steep (2-5%)
40	C	Agricultural	Very Steep (>5%)
41	C	Urban	Flat (0-1%)
42	C	Urban	Moderate (1-2%)
43	C	Urban	Steep (2-5%)
44	C	Urban	Very Steep (>5%)
45	C	Trees	Flat (0-1%)

46	C	Trees	Moderate (1-2%)
47	C	Trees	Steep (2-5%)
48	C	Trees	Very Steep (>5%)
49	D	Grass	Flat (0-1%)
50	D	Grass	Moderate (1-2%)
51	D	Grass	Steep (2-5%)
52	D	Grass	Very Steep (>5%)
53	D	Agricultural	Flat (0-1%)
54	D	Agricultural	Moderate (1-2%)
55	D	Agricultural	Steep (2-5%)
56	D	Agricultural	Very Steep (>5%)
57	D	Urban	Flat (0-1%)
58	D	Urban	Moderate (1-2%)
59	D	Urban	Steep (2-5%)
60	D	Urban	Very Steep (>5%)
61	D	Trees	Flat (0-1%)
62	D	Trees	Moderate (1-2%)
63	D	Trees	Steep (2-5%)
64	D	Trees	Very Steep (>5%)

Table 2. SAHM HSPF Pervious Parameter Values – Part I

PERLND No.	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
1	4.80	0.110	400	0.01	3.0	0.92
2	4.75	0.105	400	0.02	3.0	0.92
3	4.70	0.100	400	0.05	3.0	0.92
4	4.60	0.090	350	0.10	3.0	0.92
5	5.50	0.110	400	0.01	3.0	0.92
6	5.45	0.105	400	0.02	3.0	0.92
7	5.40	0.100	400	0.05	3.0	0.92
8	5.30	0.090	350	0.10	3.0	0.92
9	4.70	0.060	400	0.01	3.0	0.92
10	4.65	0.055	400	0.02	3.0	0.92
11	4.60	0.050	400	0.05	3.0	0.92
12	4.50	0.040	350	0.10	3.0	0.92
13	5.50	0.120	400	0.01	3.0	0.92
14	5.45	0.115	400	0.02	3.0	0.92
15	5.40	0.110	400	0.05	3.0	0.92
16	5.30	0.100	350	0.10	3.0	0.92
17	4.70	0.065	400	0.01	3.0	0.92
18	4.65	0.060	400	0.02	3.0	0.92
19	4.60	0.055	400	0.05	3.0	0.92
20	4.50	0.050	350	0.10	3.0	0.92
21	5.40	0.065	400	0.01	3.0	0.92
22	5.35	0.060	400	0.02	3.0	0.92
23	5.30	0.055	400	0.05	3.0	0.92
24	5.20	0.050	350	0.10	3.0	0.92
25	4.60	0.050	400	0.01	3.0	0.92
26	4.55	0.045	400	0.02	3.0	0.92
27	4.50	0.040	400	0.05	3.0	0.92
28	4.40	0.030	350	0.10	3.0	0.92
29	5.40	0.075	400	0.01	3.0	0.92
30	5.35	0.070	400	0.02	3.0	0.92
31	5.30	0.065	400	0.05	3.0	0.92
32	5.20	0.055	350	0.10	3.0	0.92
33	4.50	0.045	400	0.01	3.0	0.92
34	4.45	0.043	400	0.02	3.0	0.92
35	4.40	0.040	400	0.05	3.0	0.92
36	4.30	0.035	350	0.10	3.0	0.92
37	5.00	0.045	400	0.01	3.0	0.92
38	4.90	0.043	400	0.02	3.0	0.92
39	4.85	0.040	400	0.05	3.0	0.92
40	4.80	0.035	350	0.10	3.0	0.92
41	4.45	0.035	400	0.01	3.0	0.92
42	4.40	0.030	400	0.02	3.0	0.92
43	4.35	0.025	400	0.05	3.0	0.92
44	4.25	0.015	350	0.10	3.0	0.92
45	5.00	0.055	400	0.01	3.0	0.92
46	4.90	0.050	400	0.02	3.0	0.92

47	4.85	0.045	400	0.05	3.0	0.92
48	4.80	0.035	350	0.10	3.0	0.92
49	4.40	0.030	400	0.01	3.0	0.92
50	4.35	0.028	400	0.02	3.0	0.92
51	4.30	0.025	400	0.05	3.0	0.92
52	4.20	0.020	350	0.10	3.0	0.92
53	5.00	0.030	400	0.01	3.0	0.92
54	4.95	0.028	400	0.02	3.0	0.92
55	4.90	0.025	400	0.05	3.0	0.92
56	4.80	0.020	350	0.10	3.0	0.92
57	4.45	0.020	400	0.01	3.0	0.92
58	4.40	0.018	400	0.02	3.0	0.92
59	4.35	0.015	400	0.05	3.0	0.92
60	4.25	0.010	350	0.10	3.0	0.92
61	5.00	0.040	400	0.01	3.0	0.92
62	4.95	0.035	400	0.02	3.0	0.92
63	4.90	0.030	400	0.05	3.0	0.92
64	4.80	0.020	350	0.10	3.0	0.92

LZSN: Lower Zone Storage Nominal (inches)
INFILT: Infiltration (inches per hour)
LSUR: Length of surface flow path (feet)
SLSUR: Slope of surface flow path (feet/feet)
KVARY: Variable groundwater recession
AGWRC: Active Groundwater Recession Constant (per day)

Table 3. SAHM HSPF Pervious Parameter Values – Part II

PERLND No.	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
1	2.0	2.0	0.00	0.00	0.05
2	2.0	2.0	0.00	0.00	0.05
3	2.0	2.0	0.00	0.00	0.05
4	2.0	2.0	0.00	0.00	0.05
5	2.0	2.0	0.00	0.00	0.05
6	2.0	2.0	0.00	0.00	0.05
7	2.0	2.0	0.00	0.00	0.05
8	2.0	2.0	0.00	0.00	0.05
9	2.0	2.0	0.00	0.00	0.05
10	2.0	2.0	0.00	0.00	0.05
11	2.0	2.0	0.00	0.00	0.05
12	2.0	2.0	0.00	0.00	0.05
13	2.0	2.0	0.00	0.00	0.05
14	2.0	2.0	0.00	0.00	0.05
15	2.0	2.0	0.00	0.00	0.05
16	2.0	2.0	0.00	0.00	0.05
17	2.0	2.0	0.00	0.00	0.05
18	2.0	2.0	0.00	0.00	0.05
19	2.0	2.0	0.00	0.00	0.05
20	2.0	2.0	0.00	0.00	0.05
21	2.0	2.0	0.00	0.00	0.05
22	2.0	2.0	0.00	0.00	0.05
23	2.0	2.0	0.00	0.00	0.05
24	2.0	2.0	0.00	0.00	0.05
25	2.0	2.0	0.00	0.00	0.05
26	2.0	2.0	0.00	0.00	0.05
27	2.0	2.0	0.00	0.00	0.05
28	2.0	2.0	0.00	0.00	0.05
29	2.0	2.0	0.00	0.00	0.05
30	2.0	2.0	0.00	0.00	0.05
31	2.0	2.0	0.00	0.00	0.05
32	2.0	2.0	0.00	0.00	0.05
33	2.0	2.0	0.00	0.00	0.05
34	2.0	2.0	0.00	0.00	0.05
35	2.0	2.0	0.00	0.00	0.05
36	2.0	2.0	0.00	0.00	0.05
37	2.0	2.0	0.00	0.00	0.05
38	2.0	2.0	0.00	0.00	0.05
39	2.0	2.0	0.00	0.00	0.05
40	2.0	2.0	0.00	0.00	0.05
41	2.0	2.0	0.00	0.00	0.05
42	2.0	2.0	0.00	0.00	0.05
43	2.0	2.0	0.00	0.00	0.05
44	2.0	2.0	0.00	0.00	0.05
45	2.0	2.0	0.00	0.00	0.05
46	2.0	2.0	0.00	0.00	0.05

47	2.0	2.0	0.00	0.00	0.05
48	2.0	2.0	0.00	0.00	0.05
49	2.0	2.0	0.00	0.00	0.05
50	2.0	2.0	0.00	0.00	0.05
51	2.0	2.0	0.00	0.00	0.05
52	2.0	2.0	0.00	0.00	0.05
53	2.0	2.0	0.00	0.00	0.05
54	2.0	2.0	0.00	0.00	0.05
55	2.0	2.0	0.00	0.00	0.05
56	2.0	2.0	0.00	0.00	0.05
57	2.0	2.0	0.00	0.00	0.05
58	2.0	2.0	0.00	0.00	0.05
59	2.0	2.0	0.00	0.00	0.05
60	2.0	2.0	0.00	0.00	0.05
61	2.0	2.0	0.00	0.00	0.05
62	2.0	2.0	0.00	0.00	0.05
63	2.0	2.0	0.00	0.00	0.05
64	2.0	2.0	0.00	0.00	0.05

INFEXP: Infiltration Exponent
INFILD: Infiltration ratio (maximum to mean)
DEEPFR: Fraction of groundwater to deep aquifer or inactive storage
BASETP: Base flow (from groundwater) Evapotranspiration fraction
AGWETP: Active Groundwater Evapotranspiration fraction

Table 4. SAHM HSPF Pervious Parameter Values – Part III

PERLND No.	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
1	see Table 8	0.35	0.25	2.00	0.50	see Table 9
2	see Table 8	0.33	0.25	1.90	0.48	see Table 9
3	see Table 8	0.32	0.25	1.80	0.45	see Table 9
4	see Table 8	0.30	0.25	1.60	0.40	see Table 9
5	see Table 8	0.35	0.20	2.00	0.50	see Table 9
6	see Table 8	0.33	0.20	1.90	0.48	see Table 9
7	see Table 8	0.32	0.20	1.80	0.45	see Table 9
8	see Table 8	0.30	0.20	1.60	0.40	see Table 9
9	see Table 8	0.35	0.25	1.50	0.40	see Table 9
10	see Table 8	0.33	0.25	1.45	0.38	see Table 9
11	see Table 8	0.32	0.25	1.30	0.37	see Table 9
12	see Table 8	0.30	0.25	1.20	0.35	see Table 9
13	see Table 8	0.45	0.35	2.25	0.60	see Table 9
14	see Table 8	0.42	0.35	2.20	0.58	see Table 9
15	see Table 8	0.40	0.35	2.10	0.55	see Table 9
16	see Table 8	0.35	0.35	2.00	0.50	see Table 9
17	see Table 8	0.35	0.25	1.50	0.50	see Table 9
18	see Table 8	0.33	0.25	1.45	0.48	see Table 9
19	see Table 8	0.32	0.25	1.40	0.45	see Table 9
20	see Table 8	0.30	0.25	1.20	0.40	see Table 9
21	see Table 8	0.35	0.20	1.50	0.50	see Table 9
22	see Table 8	0.33	0.20	1.45	0.48	see Table 9
23	see Table 8	0.32	0.20	1.40	0.45	see Table 9
24	see Table 8	0.30	0.20	1.20	0.40	see Table 9
25	see Table 8	0.35	0.25	1.00	0.40	see Table 9
26	see Table 8	0.33	0.25	0.90	0.38	see Table 9
27	see Table 8	0.32	0.25	0.80	0.37	see Table 9
28	see Table 8	0.30	0.25	0.60	0.35	see Table 9
29	see Table 8	0.45	0.35	2.00	0.60	see Table 9
30	see Table 8	0.42	0.35	1.90	0.58	see Table 9
31	see Table 8	0.40	0.35	1.80	0.55	see Table 9
32	see Table 8	0.35	0.35	1.50	0.50	see Table 9
33	see Table 8	0.30	0.25	0.70	0.50	see Table 9
34	see Table 8	0.28	0.25	0.65	0.48	see Table 9
35	see Table 8	0.27	0.25	0.60	0.45	see Table 9
36	see Table 8	0.25	0.25	0.50	0.40	see Table 9
37	see Table 8	0.30	0.20	0.70	0.50	see Table 9
38	see Table 8	0.28	0.20	0.65	0.48	see Table 9
39	see Table 8	0.27	0.20	0.60	0.45	see Table 9
40	see Table 8	0.25	0.20	0.50	0.40	see Table 9
41	see Table 8	0.30	0.25	0.50	0.40	see Table 9
42	see Table 8	0.28	0.25	0.48	0.38	see Table 9
43	see Table 8	0.27	0.25	0.45	0.37	see Table 9
44	see Table 8	0.25	0.25	0.35	0.35	see Table 9
45	see Table 8	0.35	0.35	0.80	0.60	see Table 9
46	see Table 8	0.33	0.35	0.78	0.58	see Table 9

47	see Table 8	0.32	0.35	0.75	0.55	see Table 9
48	see Table 8	0.30	0.35	0.65	0.50	see Table 9
49	see Table 8	0.30	0.25	0.70	0.50	see Table 9
50	see Table 8	0.28	0.25	0.65	0.48	see Table 9
51	see Table 8	0.27	0.25	0.60	0.45	see Table 9
52	see Table 8	0.25	0.25	0.50	0.40	see Table 9
53	see Table 8	0.30	0.20	0.70	0.50	see Table 9
54	see Table 8	0.28	0.20	0.65	0.48	see Table 9
55	see Table 8	0.27	0.20	0.60	0.45	see Table 9
56	see Table 8	0.25	0.20	0.50	0.40	see Table 9
57	see Table 8	0.30	0.25	0.50	0.40	see Table 9
58	see Table 8	0.28	0.25	0.48	0.38	see Table 9
59	see Table 8	0.27	0.25	0.45	0.37	see Table 9
60	see Table 8	0.25	0.25	0.35	0.35	see Table 9
61	see Table 8	0.35	0.35	0.80	0.60	see Table 9
62	see Table 8	0.33	0.35	0.78	0.58	see Table 9
63	see Table 8	0.32	0.35	0.75	0.55	see Table 9
64	see Table 8	0.30	0.35	0.65	0.50	see Table 9

CEPSC: Interception storage (inches)
UZSN: Upper Zone Storage Nominal (inches)
NSUR: Surface roughness (Manning's n)
INTFW: Interflow index
IRC: Interflow Recession Constant (per day)
LZETP: Lower Zone Evapotranspiration fraction

Table 5. SAHM HSPF Pervious Parameter Values – Part IV

PERLND No.	MELEV	BELV	GWDATM	PCW	PGW	UPGW
1	400	0.00	0.00	0.15	0.17	0.20
2	400	0.00	0.00	0.15	0.17	0.20
3	400	0.00	0.00	0.15	0.17	0.20
4	400	0.00	0.00	0.15	0.17	0.20
5	400	0.00	0.00	0.15	0.17	0.20
6	400	0.00	0.00	0.15	0.17	0.20
7	400	0.00	0.00	0.15	0.17	0.20
8	400	0.00	0.00	0.15	0.17	0.20
9	400	0.00	0.00	0.15	0.17	0.20
10	400	0.00	0.00	0.15	0.17	0.20
11	400	0.00	0.00	0.15	0.17	0.20
12	400	0.00	0.00	0.15	0.17	0.20
13	400	0.00	0.00	0.15	0.17	0.20
14	400	0.00	0.00	0.15	0.17	0.20
15	400	0.00	0.00	0.15	0.17	0.20
16	400	0.00	0.00	0.15	0.17	0.20
17	400	0.00	0.00	0.15	0.17	0.20
18	400	0.00	0.00	0.15	0.17	0.20
19	400	0.00	0.00	0.15	0.17	0.20
20	400	0.00	0.00	0.15	0.17	0.20
21	400	0.00	0.00	0.15	0.17	0.20
22	400	0.00	0.00	0.15	0.17	0.20
23	400	0.00	0.00	0.15	0.17	0.20
24	400	0.00	0.00	0.15	0.17	0.20
25	400	0.00	0.00	0.15	0.17	0.20
26	400	0.00	0.00	0.15	0.17	0.20
27	400	0.00	0.00	0.15	0.17	0.20
28	400	0.00	0.00	0.15	0.17	0.20
29	400	0.00	0.00	0.15	0.17	0.20
30	400	0.00	0.00	0.15	0.17	0.20
31	400	0.00	0.00	0.15	0.17	0.20
32	400	0.00	0.00	0.15	0.17	0.20
33	400	0.00	0.00	0.15	0.17	0.20
34	400	0.00	0.00	0.15	0.17	0.20
35	400	0.00	0.00	0.15	0.17	0.20
36	400	0.00	0.00	0.15	0.17	0.20
37	400	0.00	0.00	0.15	0.17	0.20
38	400	0.00	0.00	0.15	0.17	0.20
39	400	0.00	0.00	0.15	0.17	0.20
40	400	0.00	0.00	0.15	0.17	0.20
41	400	0.00	0.00	0.15	0.17	0.20
42	400	0.00	0.00	0.15	0.17	0.20
43	400	0.00	0.00	0.15	0.17	0.20
44	400	0.00	0.00	0.15	0.17	0.20
45	400	0.00	0.00	0.15	0.17	0.20
46	400	0.00	0.00	0.15	0.17	0.20

47	400	0.00	0.00	0.15	0.17	0.20
48	400	0.00	0.00	0.15	0.17	0.20
49	400	0.00	0.00	0.15	0.17	0.20
50	400	0.00	0.00	0.15	0.17	0.20
51	400	0.00	0.00	0.15	0.17	0.20
52	400	0.00	0.00	0.15	0.17	0.20
53	400	0.00	0.00	0.15	0.17	0.20
54	400	0.00	0.00	0.15	0.17	0.20
55	400	0.00	0.00	0.15	0.17	0.20
56	400	0.00	0.00	0.15	0.17	0.20
57	400	0.00	0.00	0.15	0.17	0.20
58	400	0.00	0.00	0.15	0.17	0.20
59	400	0.00	0.00	0.15	0.17	0.20
60	400	0.00	0.00	0.15	0.17	0.20
61	400	0.00	0.00	0.15	0.17	0.20
62	400	0.00	0.00	0.15	0.17	0.20
63	400	0.00	0.00	0.15	0.17	0.20
64	400	0.00	0.00	0.15	0.17	0.20

MELEV: Mean surface elevation of the land segment (feet)
BELV: Base elevation for active groundwater (feet)
GWDATM: Datum for the groundwater elevation (feet)
PCW: Cohesion Water Porosity (fraction)
PGW: Gravitational Water Porosity (fraction)
UPGW: Upper Gravitational Water porosity (fraction)

Table 6. SAHM HSPF Pervious Parameter Values – Part V

PERLND No.	STABNO	SRRC	SREXP	IFWSC	DELTA	UELFAC	LELFAC
1	1	0.10	0.00	4.00	0.20	4.00	2.50
2	1	0.10	0.00	4.00	0.20	4.00	2.50
3	1	0.10	0.00	4.00	0.20	4.00	2.50
4	1	0.10	0.00	4.00	0.20	4.00	2.50
5	1	0.10	0.00	4.00	0.20	4.00	2.50
6	1	0.10	0.00	4.00	0.20	4.00	2.50
7	1	0.10	0.00	4.00	0.20	4.00	2.50
8	1	0.10	0.00	4.00	0.20	4.00	2.50
9	1	0.10	0.00	4.00	0.20	4.00	2.50
10	1	0.10	0.00	4.00	0.20	4.00	2.50
11	1	0.10	0.00	4.00	0.20	4.00	2.50
12	1	0.10	0.00	4.00	0.20	4.00	2.50
13	1	0.10	0.00	4.00	0.20	4.00	2.50
14	1	0.10	0.00	4.00	0.20	4.00	2.50
15	1	0.10	0.00	4.00	0.20	4.00	2.50
16	1	0.10	0.00	4.00	0.20	4.00	2.50
17	1	0.10	0.00	4.00	0.20	4.00	2.50
18	1	0.10	0.00	4.00	0.20	4.00	2.50
19	1	0.10	0.00	4.00	0.20	4.00	2.50
20	1	0.10	0.00	4.00	0.20	4.00	2.50
21	1	0.10	0.00	4.00	0.20	4.00	2.50
22	1	0.10	0.00	4.00	0.20	4.00	2.50
23	1	0.10	0.00	4.00	0.20	4.00	2.50
24	1	0.10	0.00	4.00	0.20	4.00	2.50
25	1	0.10	0.00	4.00	0.20	4.00	2.50
26	1	0.10	0.00	4.00	0.20	4.00	2.50
27	1	0.10	0.00	4.00	0.20	4.00	2.50
28	1	0.10	0.00	4.00	0.20	4.00	2.50
29	1	0.10	0.00	4.00	0.20	4.00	2.50
30	1	0.10	0.00	4.00	0.20	4.00	2.50
31	1	0.10	0.00	4.00	0.20	4.00	2.50
32	1	0.10	0.00	4.00	0.20	4.00	2.50
33	1	0.10	0.00	4.00	0.20	4.00	2.50
34	1	0.10	0.00	4.00	0.20	4.00	2.50
35	1	0.10	0.00	4.00	0.20	4.00	2.50
36	1	0.10	0.00	4.00	0.20	4.00	2.50
37	1	0.10	0.00	4.00	0.20	4.00	2.50
38	1	0.10	0.00	4.00	0.20	4.00	2.50
39	1	0.10	0.00	4.00	0.20	4.00	2.50
40	1	0.10	0.00	4.00	0.20	4.00	2.50
41	1	0.10	0.00	4.00	0.20	4.00	2.50
42	1	0.10	0.00	4.00	0.20	4.00	2.50
43	1	0.10	0.00	4.00	0.20	4.00	2.50
44	1	0.10	0.00	4.00	0.20	4.00	2.50
45	1	0.10	0.00	4.00	0.20	4.00	2.50
46	1	0.10	0.00	4.00	0.20	4.00	2.50

47	1	0.10	0.00	4.00	0.20	4.00	2.50
48	1	0.10	0.00	4.00	0.20	4.00	2.50
49	1	0.10	0.00	4.00	0.20	4.00	2.50
50	1	0.10	0.00	4.00	0.20	4.00	2.50
51	1	0.10	0.00	4.00	0.20	4.00	2.50
52	1	0.10	0.00	4.00	0.20	4.00	2.50
53	1	0.10	0.00	4.00	0.20	4.00	2.50
54	1	0.10	0.00	4.00	0.20	4.00	2.50
55	1	0.10	0.00	4.00	0.20	4.00	2.50
56	1	0.10	0.00	4.00	0.20	4.00	2.50
57	1	0.10	0.00	4.00	0.20	4.00	2.50
58	1	0.10	0.00	4.00	0.20	4.00	2.50
59	1	0.10	0.00	4.00	0.20	4.00	2.50
60	1	0.10	0.00	4.00	0.20	4.00	2.50
61	1	0.10	0.00	4.00	0.20	4.00	2.50
62	1	0.10	0.00	4.00	0.20	4.00	2.50
63	1	0.10	0.00	4.00	0.20	4.00	2.50
64	1	0.10	0.00	4.00	0.20	4.00	2.50

STABNO: User's number for the FTABLE in the FTABLES block which contains the outflow properties from the surface storage
SRRC: Surface Runoff Recession Constant (per hour)
SREXP: Surface Runoff Exponent
IFWSC: Maximum Interflow Storage Capacity when the groundwater elevation is greater than the upper influence elevation (inches)

DELTA: groundwater tolerance level used to determine transition between regions when high water table conditions are being simulated
UELFAC: multiplier on UZSN which gives the upper zone capacity
LELFAC: multiplier on LZSN which gives the lower zone capacity

The selection of the Table 5 and Table 6 default parameter values is based on limited application of these parameters in California by the staff of Clear Creek Solutions, Inc.

NOTE: The HSPF Table 5 and Table 6 parameter values are only used when using the high groundwater/wetland element. Consult first with Clear Creek Solutions, Inc., before using this element and these parameter values.

Table 7. SAHM HSPF Pervious Parameter Values – Part VI

PERLND No.	CEPS	SURS	UZS	IFWS	LZS	AGWS	GWVS
1	0.00	0.00	0.15	0.00	4.00	0.05	0.00
2	0.00	0.00	0.15	0.00	4.00	0.05	0.00
3	0.00	0.00	0.15	0.00	4.00	0.05	0.00
4	0.00	0.00	0.15	0.00	4.00	0.05	0.00
5	0.00	0.00	0.15	0.00	4.00	0.05	0.00
6	0.00	0.00	0.15	0.00	4.00	0.05	0.00
7	0.00	0.00	0.15	0.00	4.00	0.05	0.00
8	0.00	0.00	0.15	0.00	4.00	0.05	0.00
9	0.00	0.00	0.15	0.00	4.00	0.05	0.00
10	0.00	0.00	0.15	0.00	4.00	0.05	0.00
11	0.00	0.00	0.15	0.00	4.00	0.05	0.00
12	0.00	0.00	0.15	0.00	4.00	0.05	0.00
13	0.00	0.00	0.15	0.00	4.00	0.05	0.00
14	0.00	0.00	0.15	0.00	4.00	0.05	0.00
15	0.00	0.00	0.15	0.00	4.00	0.05	0.00
16	0.00	0.00	0.15	0.00	4.00	0.05	0.00
17	0.00	0.00	0.15	0.00	4.00	0.05	0.00
18	0.00	0.00	0.15	0.00	4.00	0.05	0.00
19	0.00	0.00	0.15	0.00	4.00	0.05	0.00
20	0.00	0.00	0.15	0.00	4.00	0.05	0.00
21	0.00	0.00	0.15	0.00	4.00	0.05	0.00
22	0.00	0.00	0.15	0.00	4.00	0.05	0.00
23	0.00	0.00	0.15	0.00	4.00	0.05	0.00
24	0.00	0.00	0.15	0.00	4.00	0.05	0.00
25	0.00	0.00	0.15	0.00	4.00	0.05	0.00
26	0.00	0.00	0.15	0.00	4.00	0.05	0.00
27	0.00	0.00	0.15	0.00	4.00	0.05	0.00
28	0.00	0.00	0.15	0.00	4.00	0.05	0.00
29	0.00	0.00	0.15	0.00	4.00	0.05	0.00
30	0.00	0.00	0.15	0.00	4.00	0.05	0.00
31	0.00	0.00	0.15	0.00	4.00	0.05	0.00
32	0.00	0.00	0.15	0.00	4.00	0.05	0.00
33	0.00	0.00	0.15	0.00	4.00	0.05	0.00
34	0.00	0.00	0.15	0.00	4.00	0.05	0.00
35	0.00	0.00	0.15	0.00	4.00	0.05	0.00
36	0.00	0.00	0.15	0.00	4.00	0.05	0.00
37	0.00	0.00	0.15	0.00	4.00	0.05	0.00
38	0.00	0.00	0.15	0.00	4.00	0.05	0.00
39	0.00	0.00	0.15	0.00	4.00	0.05	0.00
40	0.00	0.00	0.15	0.00	4.00	0.05	0.00
41	0.00	0.00	0.15	0.00	4.00	0.05	0.00
42	0.00	0.00	0.15	0.00	4.00	0.05	0.00
43	0.00	0.00	0.15	0.00	4.00	0.05	0.00
44	0.00	0.00	0.15	0.00	4.00	0.05	0.00
45	0.00	0.00	0.15	0.00	4.00	0.05	0.00
46	0.00	0.00	0.15	0.00	4.00	0.05	0.00

47	0.00	0.00	0.15	0.00	4.00	0.05	0.00
48	0.00	0.00	0.15	0.00	4.00	0.05	0.00
49	0.00	0.00	0.15	0.00	4.00	0.05	0.00
50	0.00	0.00	0.15	0.00	4.00	0.05	0.00
51	0.00	0.00	0.15	0.00	4.00	0.05	0.00
52	0.00	0.00	0.15	0.00	4.00	0.05	0.00
53	0.00	0.00	0.15	0.00	4.00	0.05	0.00
54	0.00	0.00	0.15	0.00	4.00	0.05	0.00
55	0.00	0.00	0.15	0.00	4.00	0.05	0.00
56	0.00	0.00	0.15	0.00	4.00	0.05	0.00
57	0.00	0.00	0.15	0.00	4.00	0.05	0.00
58	0.00	0.00	0.15	0.00	4.00	0.05	0.00
59	0.00	0.00	0.15	0.00	4.00	0.05	0.00
60	0.00	0.00	0.15	0.00	4.00	0.05	0.00
61	0.00	0.00	0.15	0.00	4.00	0.05	0.00
62	0.00	0.00	0.15	0.00	4.00	0.05	0.00
63	0.00	0.00	0.15	0.00	4.00	0.05	0.00
64	0.00	0.00	0.15	0.00	4.00	0.05	0.00

CEPS: Initial interception storage (inches)
SURS: Initial surface runoff (inches)
UZS: Initial Upper Zone Storage (inches)
IFWS: Initial interflow (inches)
LZS: Initial Lower Zone Storage (inches)
AGWS: Initial Active Groundwater storage (inches)
GWVS: Initial Groundwater Vertical Slope (feet/feet)

Table 8. SAHM HSPF Pervious Parameter Values: Monthly Interception Storage (inches)

PERLND No.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
2	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
3	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
4	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
5	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
6	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
7	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
8	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
9	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
13	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
14	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
15	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
16	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
17	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
18	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
19	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
20	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
21	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
22	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
23	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
24	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
25	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
26	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
27	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
28	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
29	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
30	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
31	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18

32	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
33	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
34	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
35	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
36	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
37	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
38	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
39	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
40	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
41	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
42	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
43	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
44	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
45	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
46	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
47	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
48	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
49	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
50	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
51	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
52	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
53	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
54	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
55	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
56	0.12	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.12
57	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
58	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
59	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
60	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
61	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
62	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
63	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18
64	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.18

Table 9. SAHM HSPF Pervious Parameter Values: Monthly Lower Zone Evapotranspiration

PERLND No.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
2	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
3	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
4	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
5	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
6	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
7	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
8	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
9	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
10	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
11	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
12	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
13	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
14	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
15	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
16	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
17	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
18	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
19	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
20	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
21	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
22	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
23	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
24	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
25	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
26	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
27	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
28	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
29	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
30	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
31	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60

32	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
33	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
34	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
35	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
36	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
37	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
38	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
39	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
40	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
41	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
42	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
43	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
44	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
45	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
46	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
47	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
48	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
49	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
50	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
51	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
52	0.40	0.40	0.40	0.45	0.50	0.55	0.55	0.55	0.55	0.55	0.45	0.40
53	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
54	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
55	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
56	0.50	0.50	0.50	0.55	0.60	0.65	0.65	0.65	0.65	0.65	0.55	0.50
57	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
58	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
59	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
60	0.50	0.50	0.50	0.60	0.65	0.65	0.65	0.65	0.65	0.65	0.55	0.50
61	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
62	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
63	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60
64	0.60	0.60	0.60	0.70	0.75	0.75	0.75	0.75	0.75	0.75	0.65	0.60

APPENDIX B: DEFAULT SAHM HSPF IMPERVIOUS PARAMETER VALUES

The default SAHM HSPF impervious parameter values are found in SAHM file defaultpers.uci.

HSPF parameter values in SAHM have been adjusted for the different soil, land cover, and land slope categories of Sacramento County based on the professional judgment and experience of Clear Creek Solutions HSPF modelers in northern California.

HSPF parameter documentation is found in the document:
Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, T.H. Jobes, and A.S. Donigian Jr. 2001. Hydrological Simulation Program – Fortran, User's Manual for Version 12. AQUA TERRA Consultants. Mountain View, CA.

Table 1. SAHM Impervious Land Types

IMPLND No.	IMPLND Name	Land Slope
1	Impervious	Flat (0-1%)
2	Impervious	Moderate (1-2%)
3	Impervious	Steep (2-5%)
4	Impervious	Very Steep (>5%)

Table 2. SAHM HSPF Impervious Parameter Values – Part I

IMPLND No.	LSUR	SLSUR	NSUR	RETSC
1	100	0.01	0.05	0.100
2	100	0.02	0.05	0.100
3	100	0.05	0.05	0.095
4	100	0.10	0.05	0.090

LSUR: Length of surface flow path (feet) for impervious area
SLSUR: Slope of surface flow path (feet/feet) for impervious area
NSUR: Surface roughness (Manning's n) for impervious area
RETSC: Surface retention storage (inches) for impervious area

Table 3. SAHM HSPF Impervious Parameter Values – Part II

IMPLND No.	RETS	SURS
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00

RETSC: Initial surface retention storage (inches) for impervious area
SURS: Initial surface runoff (inches) for impervious area

APPENDIX C: ADDITIONAL GUIDANCE FOR USING SAHM

Scope and Purpose: This appendix includes guidance and background information that are not incorporated into the SAHM software, but which the user needs to know in order to use SAHM for designing projects in the participating jurisdictions. The three main topic areas in this appendix are flagged in the main guidance documentation text by specially formatted notes under the SAHM elements or software features to which they are related:

Appendix C Topic	Relevant Sections in Guidance documentation
Infiltration Reduction Factor	Infiltration, page 74; applicable when specifying characteristics of a facility (pond, vault, tank, some LID elements) if "yes" is selected as the Infiltration option.
Flow Duration Outlet Structures (includes sizing of low-flow orifice and alternative configurations)	Outlet Structure Configurations, pages 68-73; applicable when specifying characteristics of a flow duration facility.
Drawdown (drain) time for flow duration facilities	Drawdown (Analysis screen), page 109.

This guidance was originally created by the stormwater programs of Alameda, Santa Clara, and San Mateo counties. Please consult with the local municipal permitting agency for additional considerations.

Additional guidance and references are also discussed at the end of this appendix.

Infiltration Reduction Factor

The Western Washington Hydrology Model included this factor to reflect the requirement in the *Stormwater Management Manual for Western Washington* (SMMWW), to incorporate a Correction Factor (CF) to determine long-term infiltration rates; the inverse of the CF is the Infiltration Reduction Factor in SAHM. The SMMWW gives three methods for determining CF: 1) a table providing empirical correlations between long-term infiltration rates and USDA Soil Textural Classification; 2) ASTM gradation testing at full-scale infiltration facilities; or 3) In-situ infiltration tests, preferably using a Pilot Infiltration Test specified in an appendix of the SMMWW.

Application of a CF or safety factor attempts to account for clogging and the reduction in infiltration over time, which might apply to the bottom of a flow duration pond or the top layer of a bioretention facility. However, a safety factor is also used to account for uncertainties in the available estimate of in-situ infiltration rates. The SMMWW notes that its suggested CF values, which range from 2 to 4, "represent an average degree of

long-term facility maintenance, TSS reduction through pretreatment, and site variability in the subsurface conditions", and that increases or decreases to these factors should be considered for unusual situations.

Suggested safety factors in other texts and guidance generally range from 1 to 4. Sacramento County stormwater permits may require some form of tracking and verification for treatment and hydromodification facilities. In addition, designers should not be overly conservative in selecting a very high safety factor, since this might lead to over-controlled (lower) post-project flows and an increase risk of causing impacts from deposition or sedimentation in the receiving channels. In the absence of other guidance, it is suggested that the SAHM Infiltration Reduction Factor not be less than 0.25 or greater than 0.5.

Note: Sacramento County stormwater programs may also restrict the use of infiltration for treatment purposes in certain conditions; since the flow duration facilities are also performing some treatment, designers should discuss treatment measure design with the applicable jurisdiction.

Flow Duration Outlet Structures – Practical Design Considerations

Low-flow Orifice Sizing

The diameter of the low-flow (bottom) orifice is an important design parameter for flow duration facilities, since flows discharged through this outlet should be at or below the project threshold for controlled flows (Qcp). However maintenance and/or other practical considerations may dictate a practical limit to how small this orifice may be, which may be larger than the optimal theoretical diameter determined by Auto Pond. As an example, the SWMMWW specifies a minimum orifice diameter of 0.5 inches, for flow restrictor assemblies that are within protective enclosures that screen out large particles and also have 1-2 ft of sump below the orifice to allow for some sediment accumulation.

While the user can manually set a minimum size for the low-flow orifice, doing so before running Auto Pond is not recommended as this may impair the program's ability to optimize the pond configuration. The following general approach is suggested for designing a pond when there is a small value for the low end of the flow matching range:

1. First estimate the minimum pond volume allowing Auto Pond to freely determine the diameter and placement of all orifices.
2. Then manually accept all of the pond settings except low-flow orifice diameter. Set the low-flow orifice to the desired minimum size, after consulting the local municipal permitting agency.
3. Manually run the mitigated scenario as described on page 52 and review the Analysis screen to check if the revised mitigated flow still passes the flow-

duration criteria for curve matching. If so, proceed with the pond design using the revised outlet.

4. If the revised design shows Fail scoring at one or more flow levels, excess flow durations may be reduced somewhat by reducing the depth of the pond which lowers the head above the orifice (SWMMWW recognizes a practical minimum of 3 feet of live storage if pond shallowing is required at the minimum orifice size. As an alternative, further mitigation can be applied to the low-flow orifice flow by adding an additional infiltration measure downstream. This can be sized either approximately by estimating an average excess flow from the orifice or with the help of SAHM by returning to the screen for the Pond characteristics and specifying a different Downstream Connection for the bottom orifice, which is then connected to an additional element. With this revision to the post project scenario, the Point of Compliance for the system would then be located at the downstream end of the additional low-flow mitigation.

Alternative Outlet Configurations

SAHM has two default types of outlet configurations (multiple orifice or orifice plus weir notch) based on a standpipe riser structure detailed in the SMMWW. The entire standpipe is usually within a cylindrical enclosure or manhole to exclude trash and larger particles that could clog the outlet. The SMMWW notes that orifices can also be placed on a tee section or a vertical baffle within the same type of enclosure. An alternative configuration is a flat headwall with orifices and or notches, protected by racks or gratings. This may be fabricated from a large steel plate, similar in construction to the extended detention outlets specified in the Denver (Colorado) manual referenced below. This alternative outlet can be simulated in the SAHM as a very large diameter standpipe, where the width of the top notch is equal to the overflow width at the top of the plate between its supports.

Drawdown time and treatment/vector considerations

Flow duration control facilities are designed to detain stormwater on-site for an extended period of time. The drawdown time is a concern to designers in relation to three areas of design besides hydromodification management:

1. Standing water for extended periods provides a potential habitat in which mosquitoes can breed. Sacramento stormwater programs work with their local mosquito abatement or vector control agencies to develop guidelines for stormwater facility design; these generally recommend that design detention times not exceed 96 hours. Provisions for access and inspection by vector control personnel are also required. Contact the local permitting agency for details of local vector control provisions, which apply to both treatment measures and flow duration facilities.

2. Stormwater that is detained also undergoes water quality treatment through settling and/or infiltration of pollutants. The focus of water quality management is reducing mean annual loads and typical concentrations of pollutants in receiving waters, so treatment design focuses on typical storms which contain the bulk of annual runoff volume. Stormwater permits and guidance documents describe the local design criteria for volume based treatment measures, which apply to a wider range of projects than the hydromodification management requirements. Recommended drawdown times for detention structures are typically at least 48 hours, but not to exceed 96 hours.

3. Flood control design is intended to control peak flows for large sized storms (with expected recurrence intervals such as 25, 50 or 100 years). Flood control facilities typically require capture and detention of a specified volume of stormwater, which then is discharged out at flows that can be safely conveyed by downstream channels without undue risk of flooding. Flood control facilities usually are required to drain within 24 hours after the end of the design storm in order to be empty for the next storm event. This concern that flood control storage remain available for large events has led flood control agencies to require that any storage volume for water quality not be credited for flood control, a feature that is sometimes referred to as "dead storage".

Although many factors affect the drawdown time, the suggestions below may help SAHM users in evaluating these other requirements. If flow duration control is required for a project site, it is recommended that the design process start with by using SAHM to obtain a preliminary design for the flow duration pond, vault, or tank. Then check the performance of the facility for vector control concerns, and against treatment and/or flood control design criteria as appropriate. The latter are both based on the concept of a single empirical "design storm" which does not directly correspond to the flow duration approach using frequency analysis in a long-term simulation. Stormwater treatment design requires the use of volume-based runoff coefficients, which although similar in concept to runoff coefficients used for flood control, are determined differently. Runoff coefficients used for flood control were derived for large storms with some conservatism built-in to estimates of peak flow rates and water surface elevations. Runoff coefficients for stormwater treatment have been adjusted to reflect runoff from small storms where a greater percentage of the rainfall is held within the catchment.

Vector Management

If the maximum allowed drawdown is seldom or never exceeded over the simulation period, then likelihood of mosquito breeding in the facility is very low and the design for the pond, vault or tank does not need to be modified. If a maximum allowed drawdown time is exceeded then the system may need to be redesigned to reduce the drawdown time. The designer should consider additional reductions in impervious area and/or LID elements to help reduce the facility size.

To evaluate the frequency and distribution of larger events in more detail, use the Hydrograph tool (page 110) to plot monthly peaks for several years at a time of the mitigated (post-project) scenario to get an idea of how often the discharge that corresponds to the maximum allowed drain time would be exceeded during warmer months, when mosquito development times are shortest.

Guidance by Other Agencies

Some agencies in other parts of the United States have developed extensive guidance for design of stormwater management measures. Two manuals are discussed below that provide detailed discussions or examples that may be helpful to users of SAHM, although the suitability of these recommendations for Sacramento conditions has not been verified. These documents can help provide context and ideas for users for SAHM, but adapting these ideas requires the exercise of professional engineering judgment. **Mention of the procedures and details in these documents does not imply any endorsement or guarantee that they will be appropriate for addressing the Hydromodification Management Standards in Sacramento County jurisdictions.**

Stormwater Management Manual for Western Washington (SMMWW) was prepared by the Washington Department of Ecology for implementation in 19 counties of Western Washington. The latest (2012) edition in 5 volumes is on the Web at: http://www.udfcd.org/downloads/down_critmanual.htm

Design recommendations from this manual were the basis for many features of the WWHM that have been carried over into SAHM. Portions of Volume 3 (Hydrology) that may be of interest to project designers include:

- Pages 3-2 through 3-18 illustrate several types of roof downspout controls, simple pre-engineered designs for infiltrating and/or dispersing runoff from roof areas in order to reduce runoff volume and/or increase potential groundwater recharge.
- Pages 3-50 to 3-63 discuss outlet control structures, their maintenance and source equations modeled into WWHM and SAHM
- Pages 3-75 to 3-93 regarding Infiltration Reduction Factor

Urban Storm Drain Criteria Manual by the Denver Urban Drainage and Flood Control District is on the Web at:
http://www.udfcd.org/downloads/down_critmanual.htm

Volume 3 covers design of stormwater treatment measures, including extended detention basins on pages S-66 through S-77 and structural details shown on pages SD-1 to SD-16. Although these designs are not presented for hydromodification management control, the perforated plate design concept allows fine-tuning of drawdown times and is adaptable for use in flow duration facilities.

APPENDIX D: SAHM REVIEWER CHECKLIST

SAHM Reviewer Checklist:	**Yes**	**No**
1. Received SAHM project (WHM and WH2) files?		
2. Received SAHM WDM (WDM) file?		
3. Received SAHM report file?		
4. Project (WHM) file loads okay?		
5. Project location matches location on SAHM screen?		
6. Pre-project scenario runs okay?		
7. Mitigated scenario runs okay?		
8. Compare SAHM Report screen with report file:		
a. Project location descriptions match?		
b. Precipitation gages match?		
c. Precipitation scales match?		
d. Flow frequency results match?		
e. All flow duration values PASS?		
f. Any pervious (PERLND) land use changes?		
g. Any impervious (IMPLND) land use changes?		
h. Any scaling factor changes?		
i. Any duration criteria changes?		
j. pond dimensions match?		
k. pond outlet structure info matches?		
9. SAHM pond dimensions match drawings?		
10. Infiltration set to YES for infiltration pond?		
11. Total SAHM drainage area matches drainage maps/drawings?		
12. Mitigated drainage area(s) match Pre-project?		
13. Pre-project vegetation correct?		
14. Mitigated land use areas correct?		
15. Routing correct?		
16. Check facility drawdown (if included):		
a. Used POC Mitigated stage?		
b. Drawdown times okay?		
17. Options set to default values?		
18. Other issues?		
SAHM submittal APPROVED?		

Below is a complete list of the files produced by SAHM:

Project file: .WHM
Project back-up file: .WH2 (text file)
Project database file: .WDM (HSPF WDM binary file)
Project report file: .RTF (Microsoft Word rich text file format)
Project report file: .PDF (portable document format)
Project HSPF input file: .UCI (HSPF text file)
Project HSPF message file: .MES (HSPF text file)
Project HSPF PERLND output file: .L61 (HSPF text file)
Project HSPF RCHRES output file: .L62 (HSPF text file)
Project HSPF data output file: .DAT (HSPF text file)
Project HSPF error file: ERROR.FIL (HSPF text file)

Note: Only the project file is needed to run or check a model. SAHM will create the additional files, as needed.

APPENDIX E: BIORETENTION MODELING METHODOLOGY

The bioretention swale element is also known as a landscape swale or rain garden. The SMRHM bioretention swale element is a special conveyance feature with unique characteristics. The element uses the HSPF hydraulic algorithms to route runoff, but the HSPF routing is modified to represent the two different flow paths that runoff can take. The routing is dependent on the inflow to the swale and the swale soil capacity to absorb additional runoff. HSPF Special Actions is used to check the swale soil capacity to determine the appropriate routing option.

A bioretention swale is a swale in which the native soils have been excavated and replaced with amended soil. At the downstream end of the swale a weir or riser controls the surface discharge from the swale and detains runoff, encouraging it to infiltrate into the amended soil. Infiltration from the amended soil to the native soil is also possible, depending on the properties of the native soil. Swales can include an underdrain pipe.

The amended soil placed in the swale is assumed to have storage capacity equal to its porosity and volume. Runoff infiltrates from the surface of the swale to the amended soil at an infiltration rate set by the user. The infiltration rate cannot exceed the available storage capacity of the amended soil. The available storage capacity is determined each time step by HSPF Special Actions. Once the amended soil is saturated then water has the opportunity to infiltrate into the underlying native soil at the native soil's infiltration rate. The native soil infiltration is input by the user and is assumed to be constant throughout the year.

Inflow to the swale can exceed the amended soil infiltration rate. When this occurs the extra water ponds on the surface of the swale. The extra water can then infiltrate into the soil during the next time step or can flow out of the swale through its surface outlet if the ponding exceeds the surface outlet's storage.

Runoff in both the surface storage and amended soil storage is available for evapo-transpiration. Surface storage evapotranspiration is set to the potential evapo-transpiration; the amended soil evapotranspiration pan evaporation factor is set to 0.50 to reflect reduced evapotranspiration from the amended soil.

In the amended soil water movement through the soil column is dependent on soil layer characteristics and saturation rates for different discharge conditions.

Consider a simple two-layered bioretention facility designed with two soil layers with different characteristics. As water enters the facility at the top, it infiltrates into the soil based on the modified Green Ampt equation (Equation 1). The water then moves through the top soil layer at the computed rate, determined by Darcy's and Van Genuchten's equations. As the soil approaches field capacity (i.e., gravity head is greater than matric head), we can determine when water will begin to infiltrate into the second

layer (lower layer) of the soil column. This occurs when the matric head is less than the gravity head in the first layer (top layer).

Since the two layers have different soil characteristics, water will move through the two layers at different rates. Once both layers have achieved field capacity then the layer that first becomes saturated is determined by which layer is more restrictive. This is determined by using Darcy's equation to compute flux for each layer at the current level of saturation. The layer with the more restrictive flux is the layer that becomes saturated for that time step. The next time step the same comparison is made.

The rate and location of water discharging from the soil layer is determined by the discharge conditions selected by the user.

There are four possible combinations of discharge conditions:

1. There is no discharge from the subsurface layers (except for evapotranspiration). This means that there is no underdrain and there is no infiltration into the native soil. Which this discharge condition is unlikely, we still need to be able to model it.

2. There is an underdrain, but no native infiltration. Discharge from the underdrain is computed based on head conditions for the underdrain. The underdrain is configured to have an orifice. (It is possible for the orifice to be the same diameter as the underdrain.) With a maximum of three soil layers determining head conditions for the orifice is complicated. Each modeled layer must overcome matric head before flow through the underdrain can begin. Once matric head is overcome by gravity head for all of the layers then the underdrain begins to flow. The flow rate is determined based on the ability of the water to move through the soil layers and by the discharge from the orifice, whichever is smaller. Head conditions are determined by computing the saturation level of the lowest soil layer first. Once the lowest soil layer is saturated and flow begins then the gravity head is considered to be at the saturation level of the lowest soil layer. Once the lowest soil layer is saturated completely then the head will include the gravity head from the next soil layer above until gravity head from all soil layers is included. Gravity head from ponding on the surface is included in the orifice calculations only if all of the intervening soil layers are saturated.

3. There is native infiltration but no underdrain. Discharge (infiltration) into the native soil is computed based a user entered infiltration rate in units of inches per hour. Specific head conditions are not used in determining infiltration into the native soil. Any impact due to head on the infiltration rate is considered to be part of the determination of the native soil infiltration rate. Because it is possible to have a maximum of three soil layers, each modeled layer must overcome matric head before infiltration to the native soil can begin. Once matric head is overcome by gravity head for all modeled layers then infiltration begins at a maximum rate determined either by the ability of the water to move through the

soil layers or by the ability of the water to infiltrate into the native soil, whichever is limiting.

4. There is both an underdrain and native infiltration. Underdrain flow and native infiltration are computed as discussed above. However, there is one other limitation to consider. In the case where the flow through the soil layer is less than the sum of the discharge through the underdrain and the native infiltration then the flow through the soil layer becomes the limiting flow and must be divided between the native infiltration and the underdrain. This division is done based on the relative discharge rates of each.

Note that wetted surface area can be included in the discharge calculations by adding the infiltration through the wetted surface area to the lower soil layer and the upper surface layer individually. This is done by computing the portion of the wetted surface area that is part of the upper surface layer and computing the infiltration independently from the portion of the wetted surface area that is part of the lower soil layers.

There are several equations used to determine water movement from the surface of the bioretention facility, through the soil layers, and into an underdrain or native infiltration. The water movement process can be divided into three different zones:

1) Surface ponding and infiltration into the top soil layer (soil layer 1)
2) Percolation through the subsurface layers
3) Underdrain flow and native infiltration

The modified Green Ampt equation (Equation 1) controls the infiltration rate into the top soil layer:

$$f = K\left(1 + \frac{(\phi - \theta)(d + \varphi)}{F}\right) \qquad \text{(Equation 1)}$$

f = soil surface infiltration rate (cm/hr)
ϕ = soil porosity of top soil layer
θ = soil moisture content of top soil layer
φ = suction head at the wetting front (cm)
F= soil moisture content of the top soil layer (cm)
d= surface ponding depth (cm)
K= hydraulic conductivity based on saturation of top soil layer (cm/hr)

K (relative hydraulic conductivity) can be computed using the following Van Genuchten approximation equation:

Van Genuchten approximation of relative hydraulic conductivity

$$\frac{K(\theta)}{K_{sat}} = \left(\frac{\theta - \theta_r}{\phi - \theta_r}\right)^{1/2}\left[1 - \left(1 - \left(\frac{\theta - \theta_r}{\phi - \theta_r}\right)^{1/m}\right)^m\right]^2 \qquad \text{(Equation 2)}$$

where $K(\theta)$ = relative hydraulic conductivity,
K_{sat} = saturated hydraulic conductivity,
θ = water content, θ_r = residual water content,
ϕ = porosity, α = constant, n = constant, m = constant

A few issues arise when dealing with multiple subsurface soil layers. The K value used in Equation 1 must be computed from the top soil layer. Infiltration into the upper soil layer must not exceed the lesser of the maximum percolation rates for each of the soil layers. Finally, the rate of percolation of the top layer may be reduced because the layer or layers beneath the top layer cannot accept the percolation flux because of existing saturation levels.

Water storage and movement through the three subsurface layers will be computed using Darcy's equation as shown below:

$$q = -K\frac{\partial h}{\partial z} \qquad \text{(Equation 3)}$$

Where:

q = Darcy flux (cm/hr)

K = hydraulic conductivity of the porous medium (cm/hr)

h = total hydraulic head (cm)

z = elevation (cm)

The total head, h, is the sum of the matric head, ψ, and the gravity head, z:

$$h = \psi + z\ . \qquad \text{(Equation 4)}$$

Substituting for h yields:

$$q = -K\frac{d(\psi + z)}{dz}\ . \qquad \text{(Equation 5)}$$

Hydraulic conductivity and matric head vary with soil moisture content. These values can be computed by solving the Van Genuchten's equation (Equation 6) for both values. Note that $\psi = 0$ when the soil is saturated.

Van Genuchten Equation to calculate total head

$$h = -\frac{1}{\alpha}\left[\frac{1}{SE^{1/m}} - 1\right]^{1/n} + z \qquad \text{(Equation 6)}$$

where h = total hydraulic head, α = constant, SE = effective saturation, m = constant, n = constant, and z = elevation head

Effective saturation (SE) can be computed using the following Van Genuchten equation:

Van Genuchten Equation to calculate effective saturation

$$\frac{\theta - \theta_r}{\phi - \theta_r} = \left[\frac{1}{1 + (\alpha\psi)^n}\right]^m = SE \qquad \text{(Equation 7)}$$

where θ = water content, θ_r = residual water content,
ϕ = porosity,
α = constant = $y_b - 1$,
n = constant = $\lambda + 1$,
m = constant = $1 - \frac{1}{\lambda + 1}$,
λ = pore size distribution index,
y_b = bubbling pressure
ψ = pressure head = h-z, h = total hydraulic head,
z = elevation head, and SE = effective saturation

Ignoring z (elevation head) results in h = hm (matric head).

Evapotranspiration is an important component of the bioretention facility's hydrologic processes. Evapotranspiration removes water from bioretention surface ponding and the soil column during non-storm periods. The routine will satisfy potential evapo-transpiration (PET) demands in the same sequence as implemented in HSPF:

1. Water available from vegetation interception storage
2. Water available from surface ponding
3. Water available from the bioretention soil layers (top layer first)

Water will be removed from vegetation interception storage and surface ponding and the bioretention soil layers (starting at the top layer) down to the rooting depth at the potential rate. Water is taken from the soil layers below the rooting depth based on a percentage factor to be determined. Without this factor there will be no way to remove water from below the rooting depth once it becomes completely saturated.

APPENDIX F: SAHM COMPLEX PROJECT EXAMPLE

A complex project site with multiple stormwater mitigation facilities and multiple points of compliance can easily be modeled with SAHM. The key to successful stormwater modeling of a complex project site is to approach the modeling in a systematic way. The following is an example of how that can be done in SAHM.

It is important to first lay out what the project area looks like prior to development and then with the proposed new development. For this example we will assume that we have a large project area of 470 acres with three locations where stormwater flows off of the project area and into adjacent stream and stormwater conveyance systems. Using an Excel spreadsheet we will identify the pre-project and developed land use for the area draining to each of the points of compliance (POCs).

Pre-project:

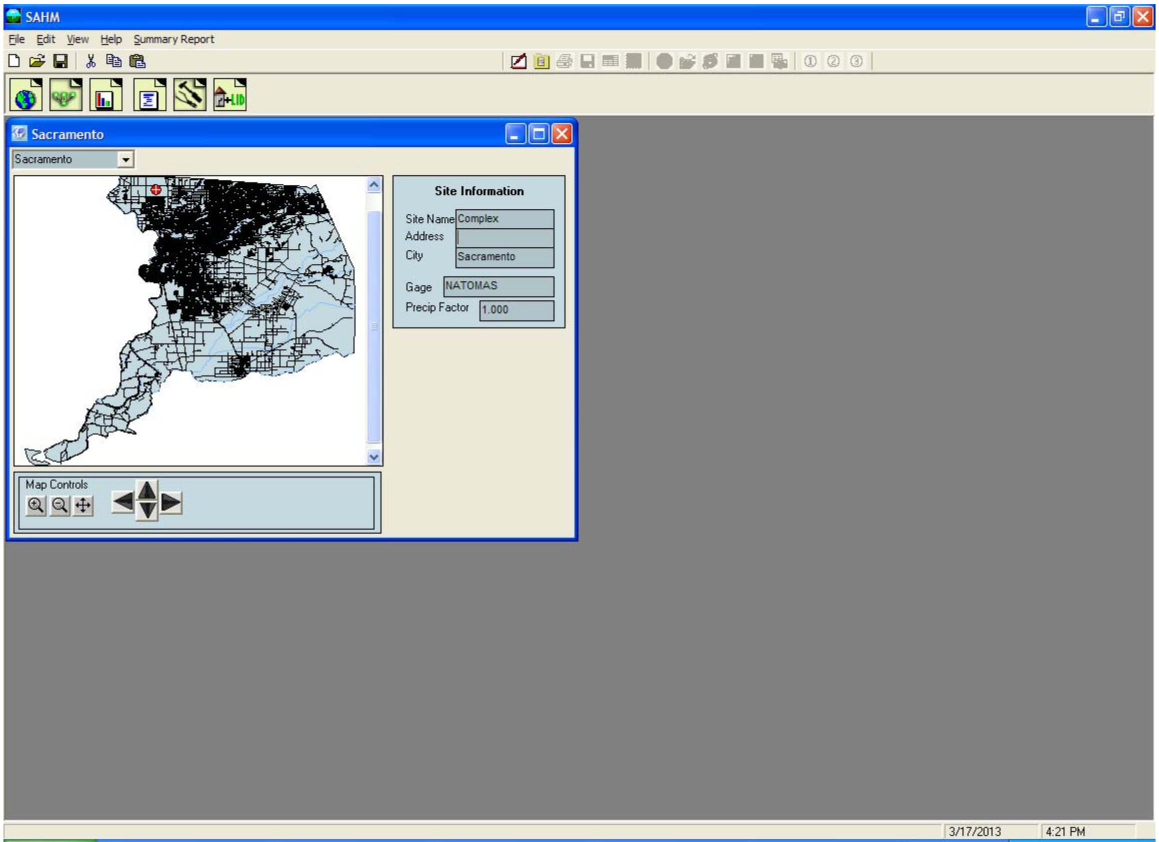
SAHM Complex Project Example								
Total Project Area			**470**					
DMA 1:	**North Area**							
Drains to:	**POC 1**							
Pre-project					**1A**	**1B**	**1C**	**Total**
Total drainage area:			**260**	**ac**	**36**	**70**	**154**	**260**
soil	cover	slope						
C	grass	steep	6	ac	6	0	0	6
C	agriculture	moderate	160	ac	30	60	70	160
D	grass	moderate	9	ac	0	9	0	9
D	agriculture	flat	82	ac	0	0	82	82
impervious		moderate	3	ac	0	1	2	3
Total drainage area:			260	ac	36	70	154	260
DMA 2:	**East Area**							
Drains to:	**POC 2**							
Pre-project					**2A**	**2B**	**Pond**	**Total**
Total drainage area:			**83**	**ac**	**21**	**61**	**1**	**83**
soil	cover	slope						
C	grass	steep	1	ac	1	0		1
C	agriculture	moderate	48	ac	9	39		48
D	grass	moderate	1	ac	1	0		1
D	agriculture	flat	32	ac	10	22		32
existing	pond		1	ac	0	0	1	1
Total drainage area:			83	ac	21	61	1	83
DMA 3:	**South Area**							
Drains to:	**POC 3**							
Pre-project								
Total drainage area:			**127**	**ac**				
soil	cover	slope						
C	grass	steep	1.5	ac				
C	agriculture	moderate	28	ac				
D	grass	moderate	0	ac				
D	agriculture	flat	96	ac				

impervious	moderate	1.5	ac
Total drainage area:		127	ac

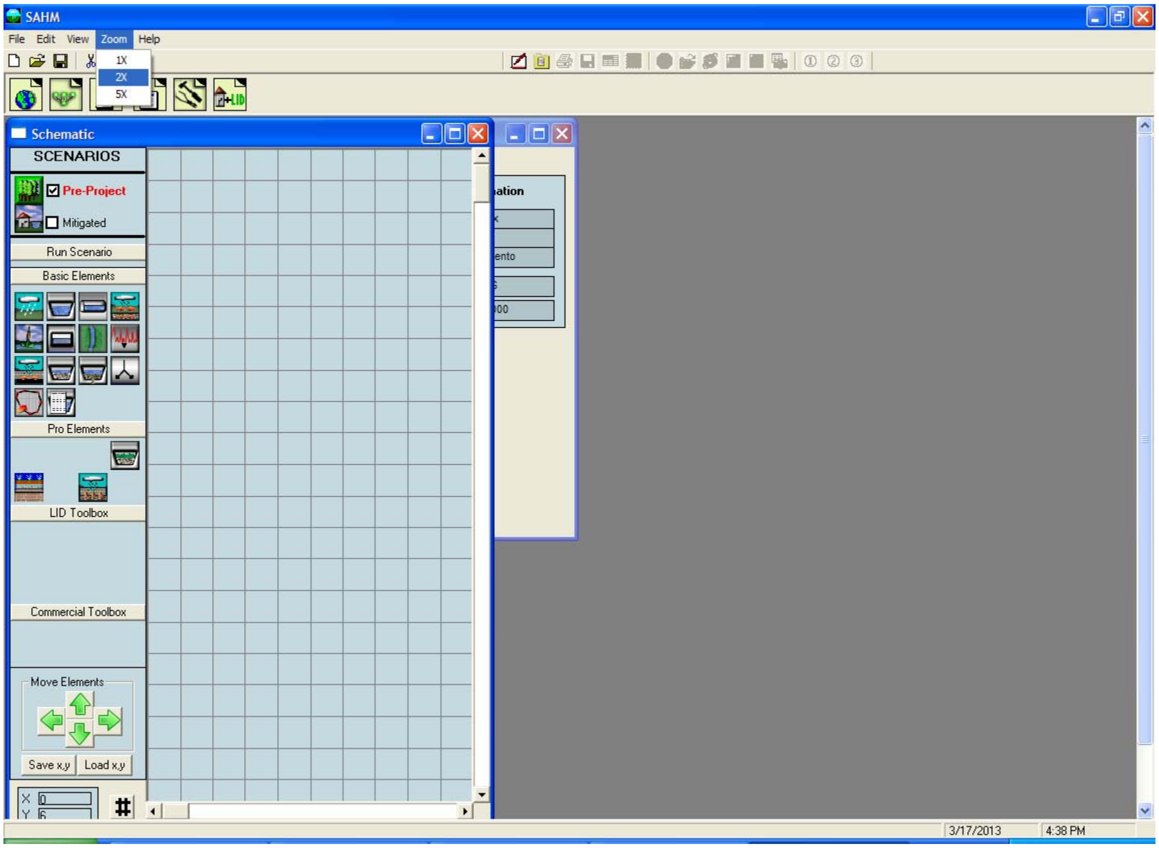
Developed:

SAHM Complex Project Example									
Total Project Area			**470**						
DMA 1:	**North Area**								
Drains to:	**POC 1**								
Developed					**1A**	**1B**	**1C**	**Other**	**Total**
Total drainage area:			**260**	**ac**	**36**	**70**	**144**	**10**	**260**
soil	cover	slope							
C	urban	moderate	60	ac	31		29		60
D	urban	moderate	40	ac			40		40
impervious		flat	150	ac	5	70	75		150
	pond		10					10	10
Total drainage area:			260	ac	36	70	144	10	260
DMA 2:	**East Area**								
Drains to:	**POC 2**								
Developed					**2A**	**2B**	**Pond**	**Other**	**Total**
Total drainage area:			**83**	**ac**	**15**	**57**	**5**	**6**	**83**
soil	cover	slope							
C	urban	moderate	1	ac	1	0			1
D	grass	moderate	3	ac	0	0		3	3
impervious	lateral to grass	moderate	3	ac	0	0		3	3
impervious		moderate	71	ac	14	57			71
existing	pond		1	ac	0	0	1		1
new	pond		4	ac			4		4
Total drainage area:			83	ac	15	57	5	6	83
DMA 3:	**South Area**								
Drains to:	**POC 3**								
Developed									
Total drainage area:			**127**	**ac**					
soil	cover	slope							
C	urban	moderate	7	ac					
green roof		flat	1	ac					
impervious		flat	82	ac					
permeable	pavement	moderate	30	ac					
bioretention		flat	7	ac					
Total drainage area:			127	ac					

The development project is going to convert mostly agricultural land into a commercial and residential subdivision. There is an existing pond in DMA 2 that will be included in the final development. The development will also include permeable pavement (DMA 3), lateral flow dispersion (DMA 2), green roof (DMA 3), and bioretention (DMA 3), in addition to stormwater ponds/detention basins in DMAs 1 and 2.



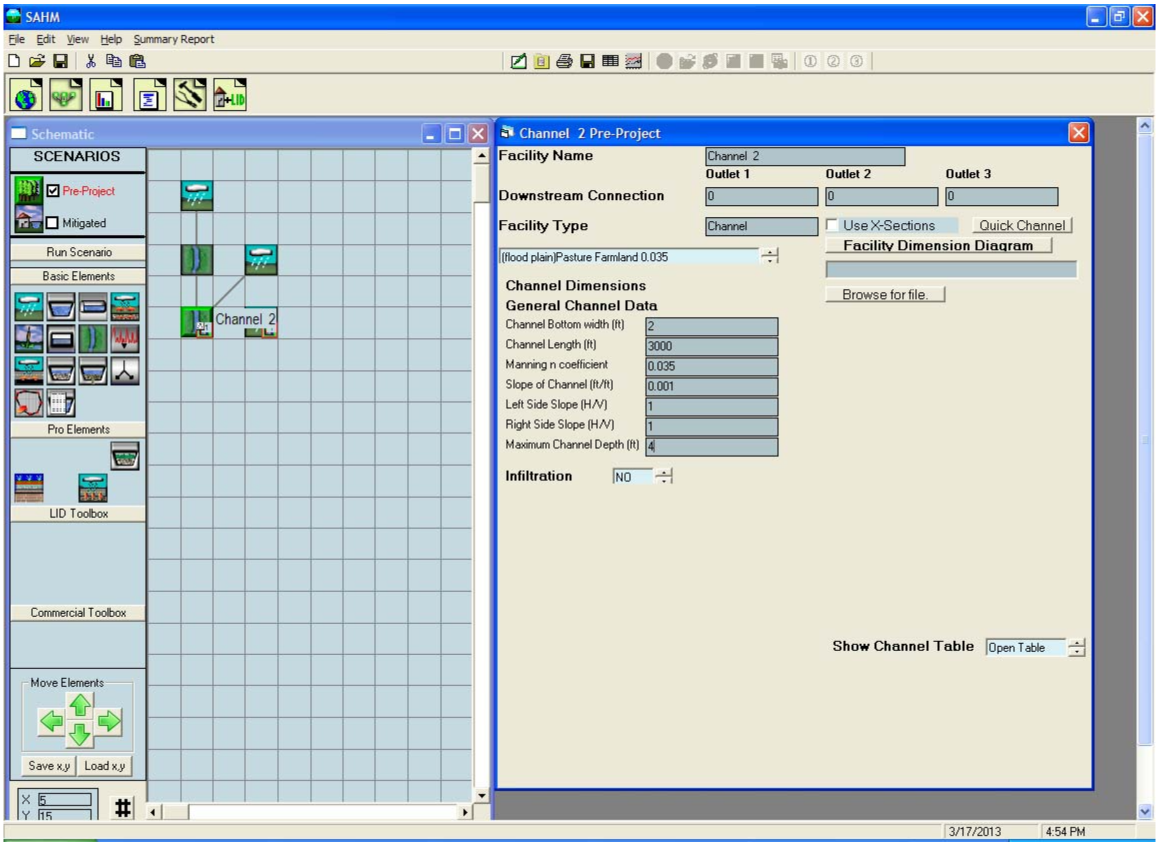
The project site is in the northwestern part of the county. The Natomas precipitation record will be used with a precipitation multiplication factor of 1.00.



The project is going to include a large number of elements so to show more elements on the schematic grid at one time we use the Zoom feature to double (2X) the number of grid cells.

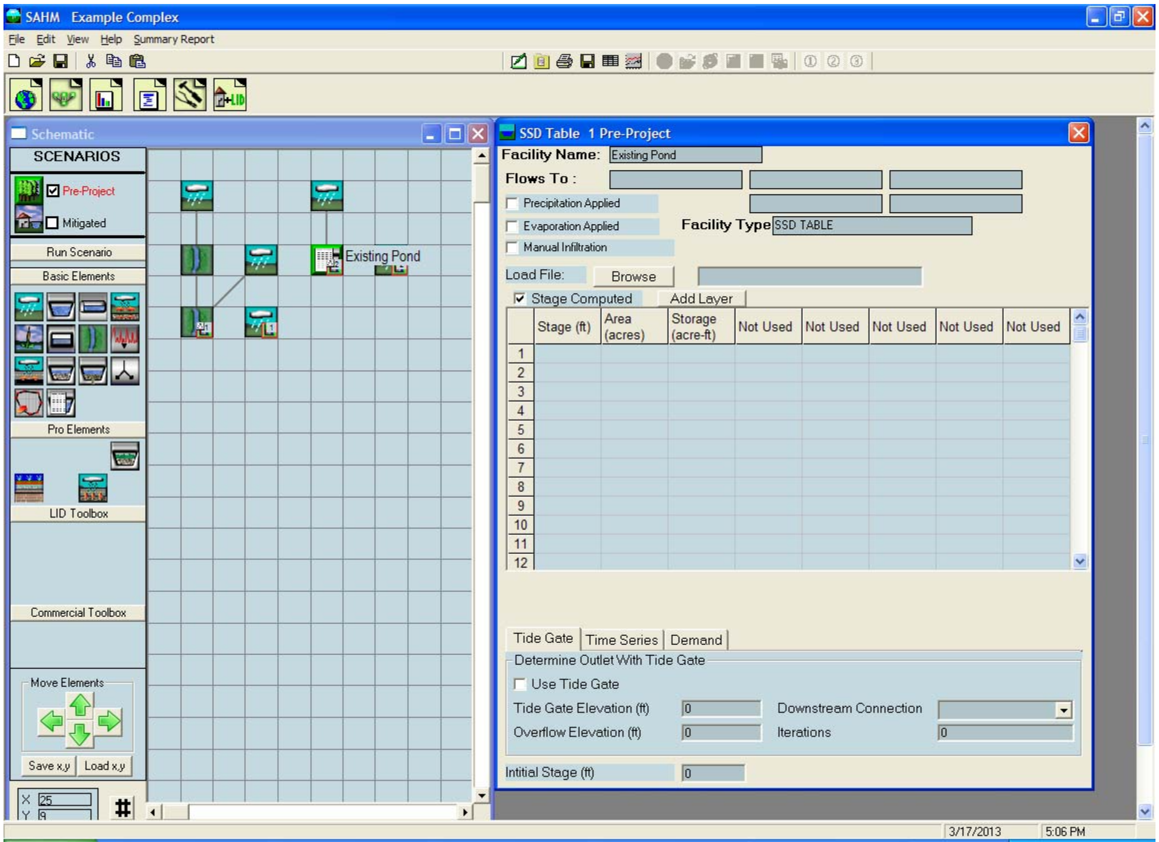
We will start with DMA 1. Because of the size of this DMA (260 acres), the stormwater travel time, and the existence of agricultural drainage ditches we will include two channel reaches to provide routing time between the upstream end of the DMA and the downstream POC. We are using a one-hour time step so the routing time through each channel reach should equal approximately one hour.

Also, because of the large size of the drainage areas we see evidence of groundwater flowing into the existing conveyance systems as base flow. Therefore, we include groundwater in our point of compliance calculations and add it to surface runoff and interflow (shallow, sub-surface runoff) to calculate the total stormwater runoff.



DMA 1A (36 acres) drains into the upstream channel reach (Channel 1). DMA 1B (70 acres) drains into the downstream channel reach (Channel 2). Channel 2 discharges at the point of compliance (POC 1). DMA 1C (154 acres) also drains to POC 1 but is not connected to Channel 2 because it is sufficiently close to the POC that routing the DMA 1C runoff through the length of Channel 2 would not be accurate.

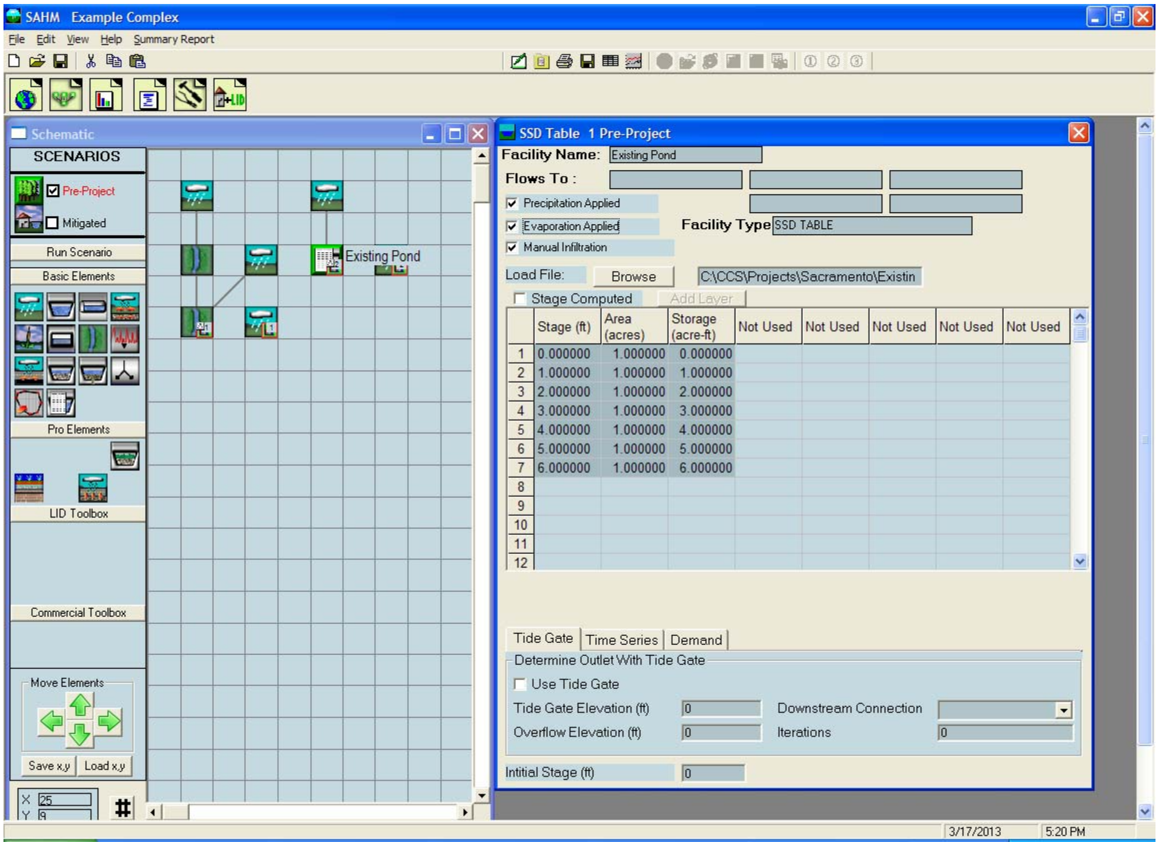
We will set up all three pre-project DMAs before running the pre-project scenario.



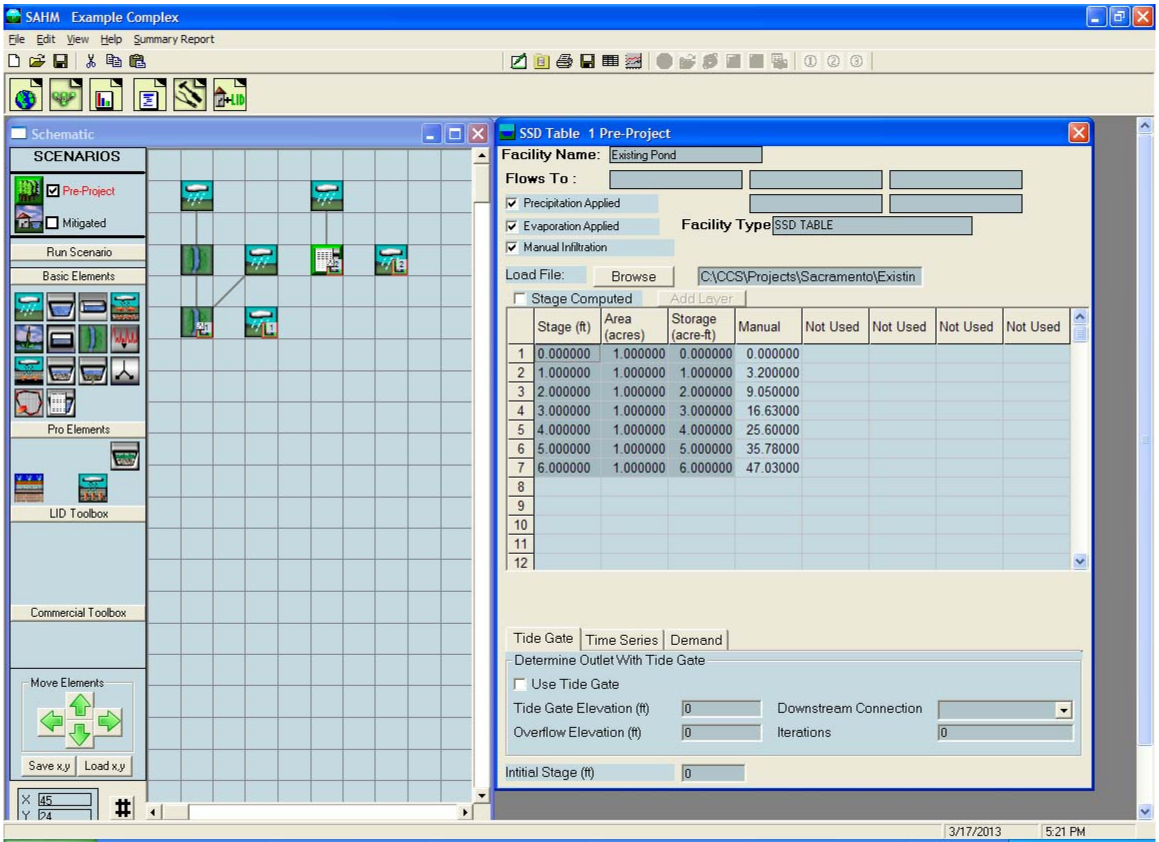
The runoff from DMA 2A flows to the DMA 2 existing pond. The DMA 2 existing pond can be represented by the SSD Table element. The SSD (Stage-Storage-Discharge) Table allows us to input the stage-storage-discharge relationship for any routing element. We can create the SSD Table values in an Excel spreadsheet.

Elevation (ft)	Stage (ft)	Surface Area (ac)	Storage Volume (ac-ft)	Discharge (cfs)
54.00	0.00	1.00	0.00	0.00
55.00	1.00	1.00	1.00	3.20
56.00	2.00	1.00	2.00	9.05
57.00	3.00	1.00	3.00	16.63
58.00	4.00	1.00	4.00	25.60
59.00	5.00	1.00	5.00	35.78
60.00	6.00	1.00	6.00	47.03

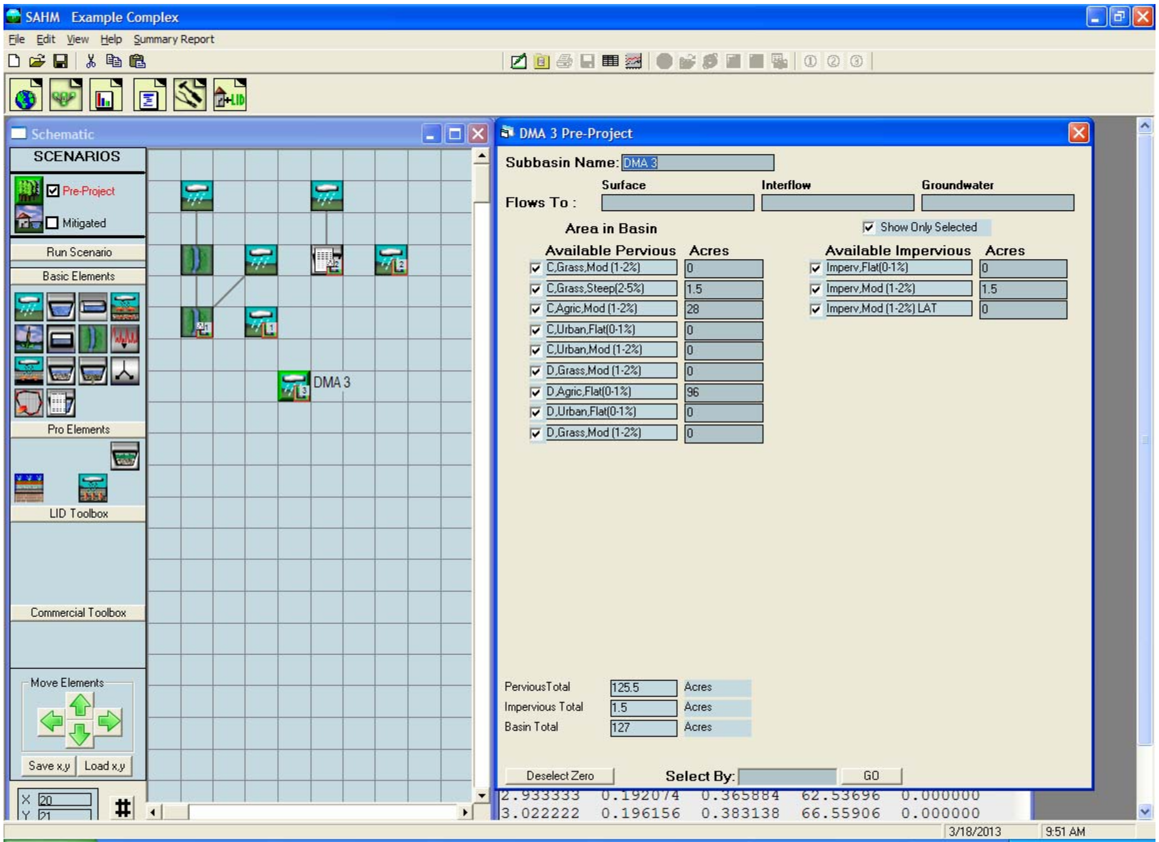
We copy the stage, surface area, storage volume, and discharge values (excluding the headings) into an Excel CSV (comma-delimited) file to import into SAHM. The elevation column is not needed and is not included.



The stage, area, and storage are automatically copies into the SSD Table. To get the discharge column we click on “Not Used” in column 4 and select “Manual”.

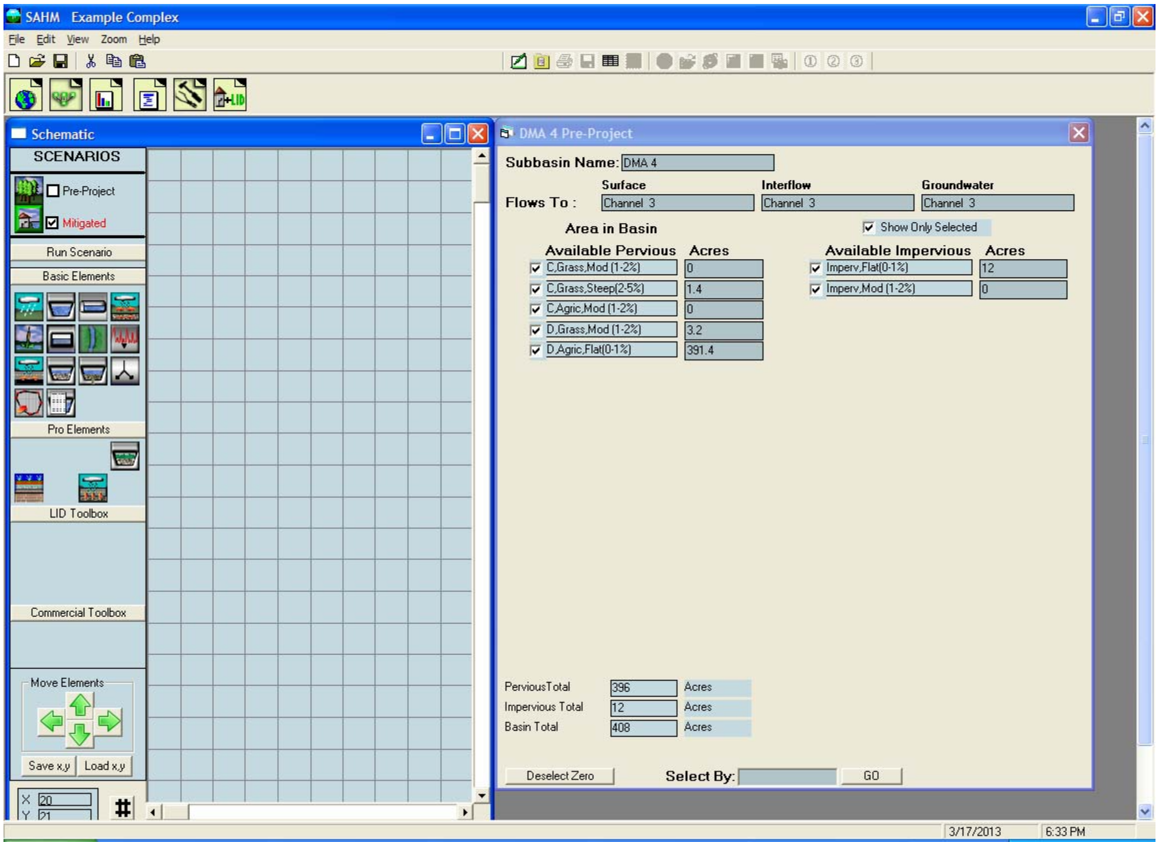


We connect the discharge from the DMA 2 existing pond and the runoff from DMA 2B to POC 2.

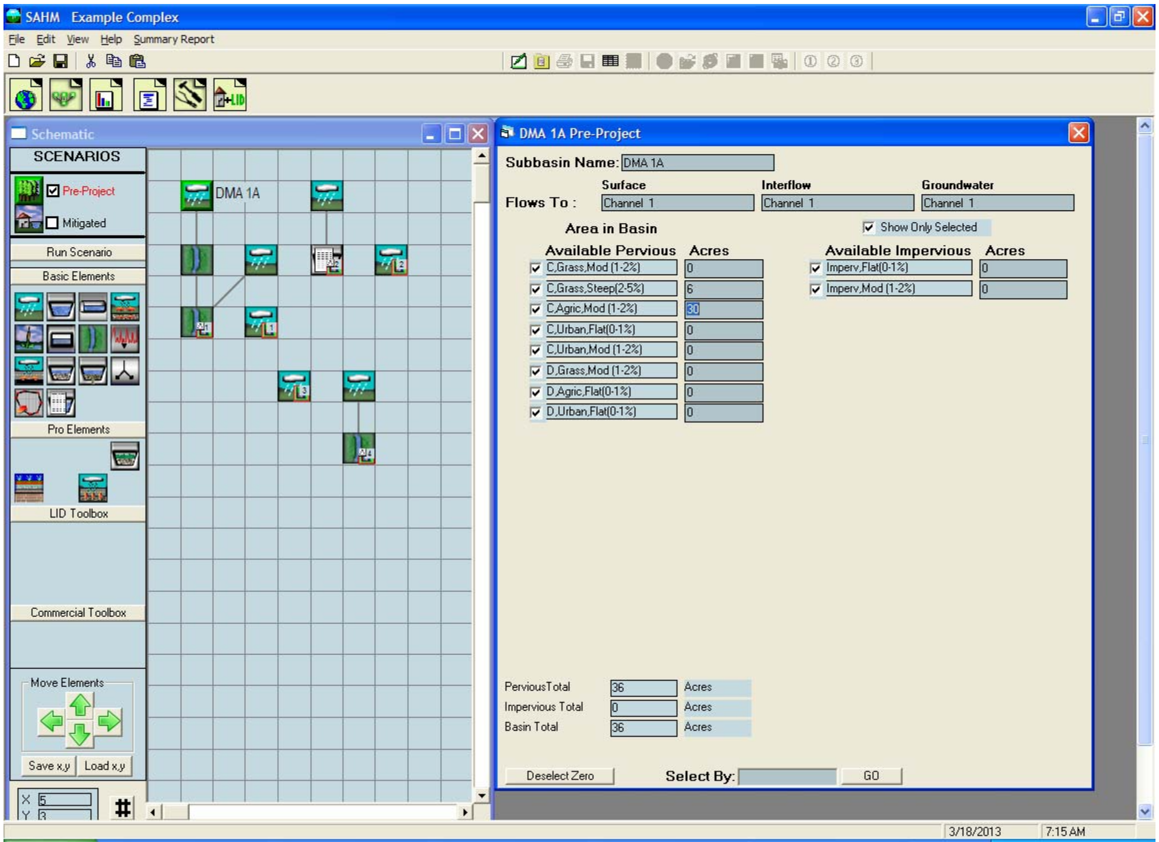


The input for DMA 3 is added. It doesn't matter where DMA 3 placed on the grid as long as it is connected to the correct POC.

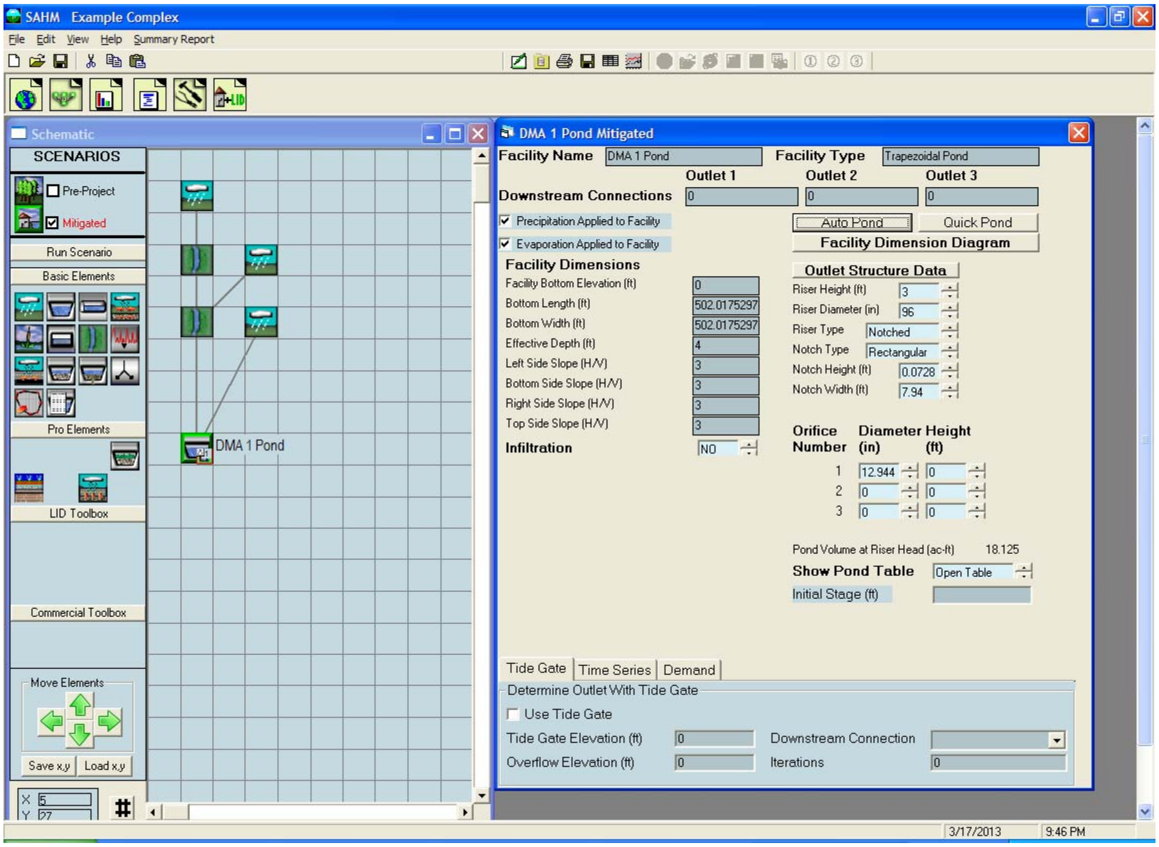
We run the pre-project scenario and when it finishes we go to the mitigated scenario grid.



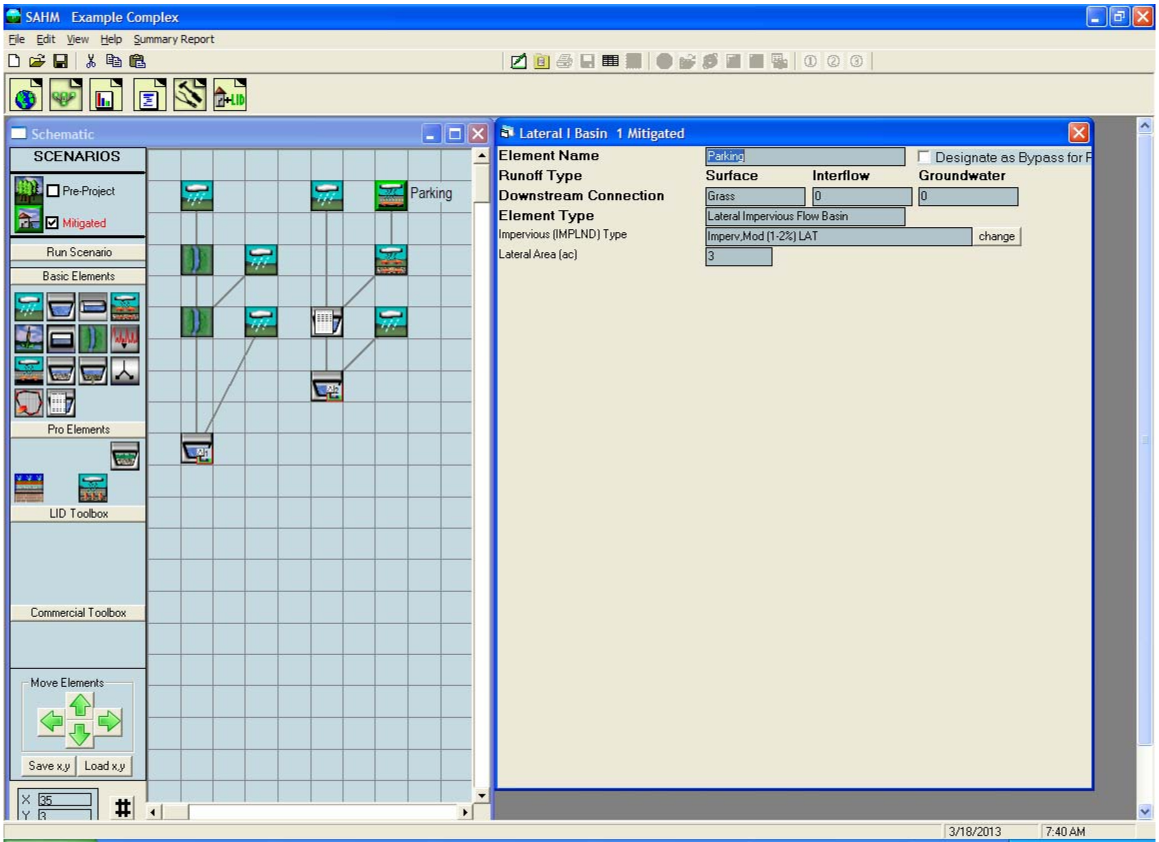
For the developed mitigated scenario we will be sizing the stormwater mitigation facilities to meet the HMP flow duration requirements. It is easiest to do this one DMA at a time. We will start with DMA 1.



In DMA 1 the two open channels remain and will now drain to a stormwater detention pond. The grass and agricultural land has been converted to urban vegetation (lawn, flowers, and shrub irrigated landscaping) and impervious areas (roads, roofs, sidewalks, etc.). Everything drains to DMA 1 Pond. The discharge from DMA 1 Pond is the mitigated POC 1. We can now size DMA 1 Pond using the Auto Pond option.

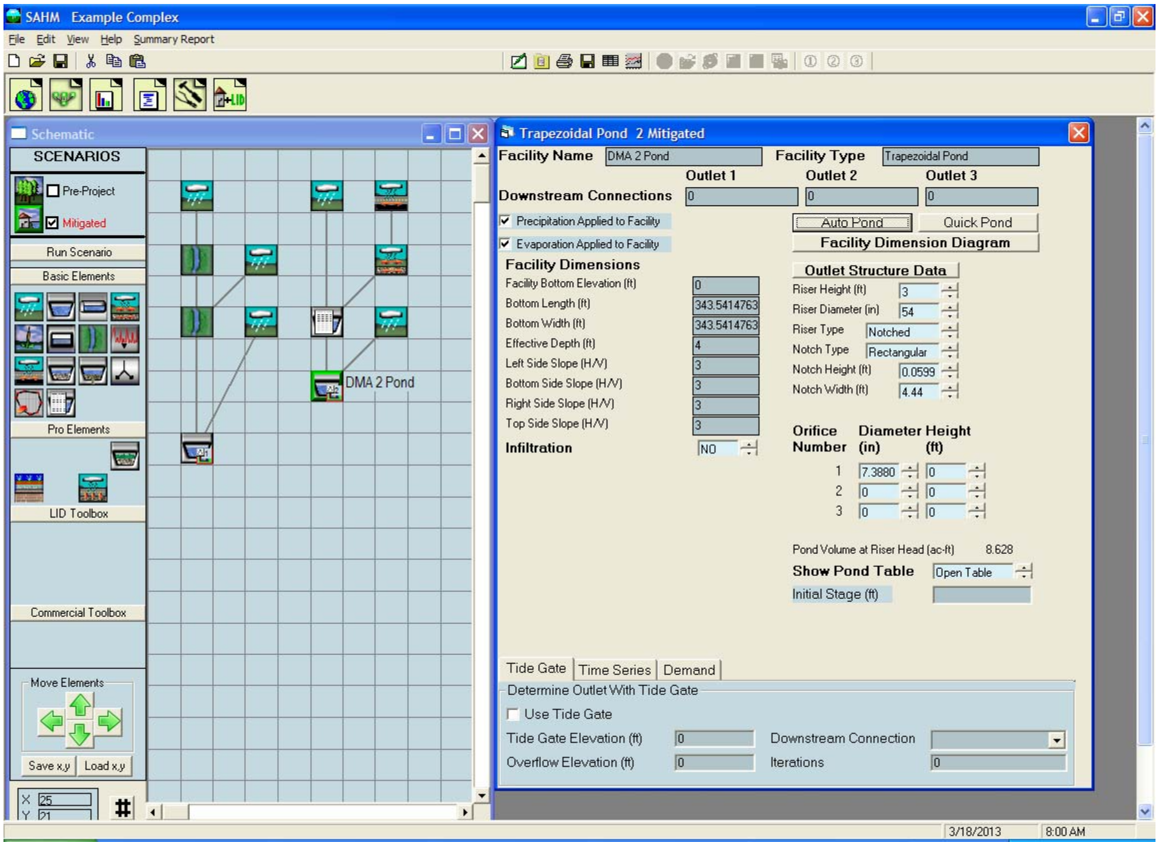


We have now sized the DMA 1 Pond.



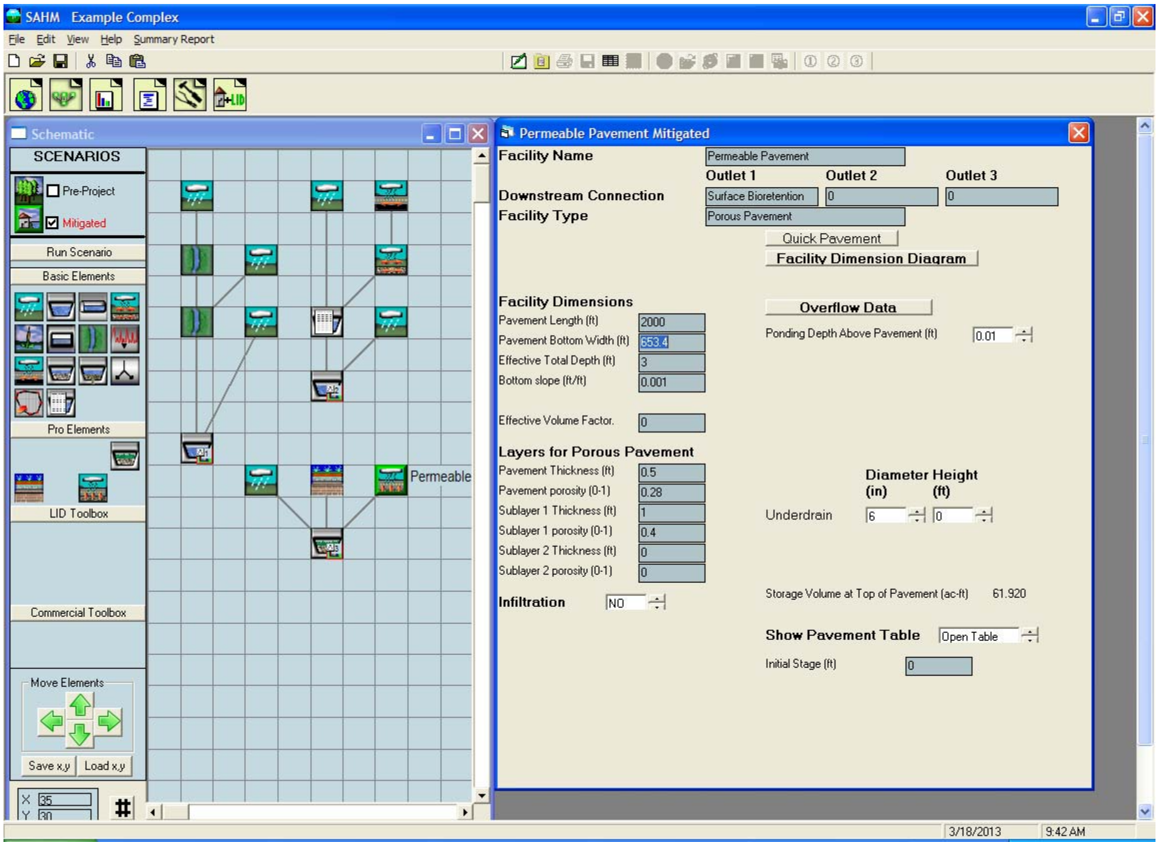
For DMA 2 we are including 3 acres of parking that sheet flows onto 3 acres of grass before entering the existing pond on site. We use the lateral flow basins to represent the parking and grass areas for this situation.

All of the runoff eventually drains to the stormwater detention pond at POC 2.

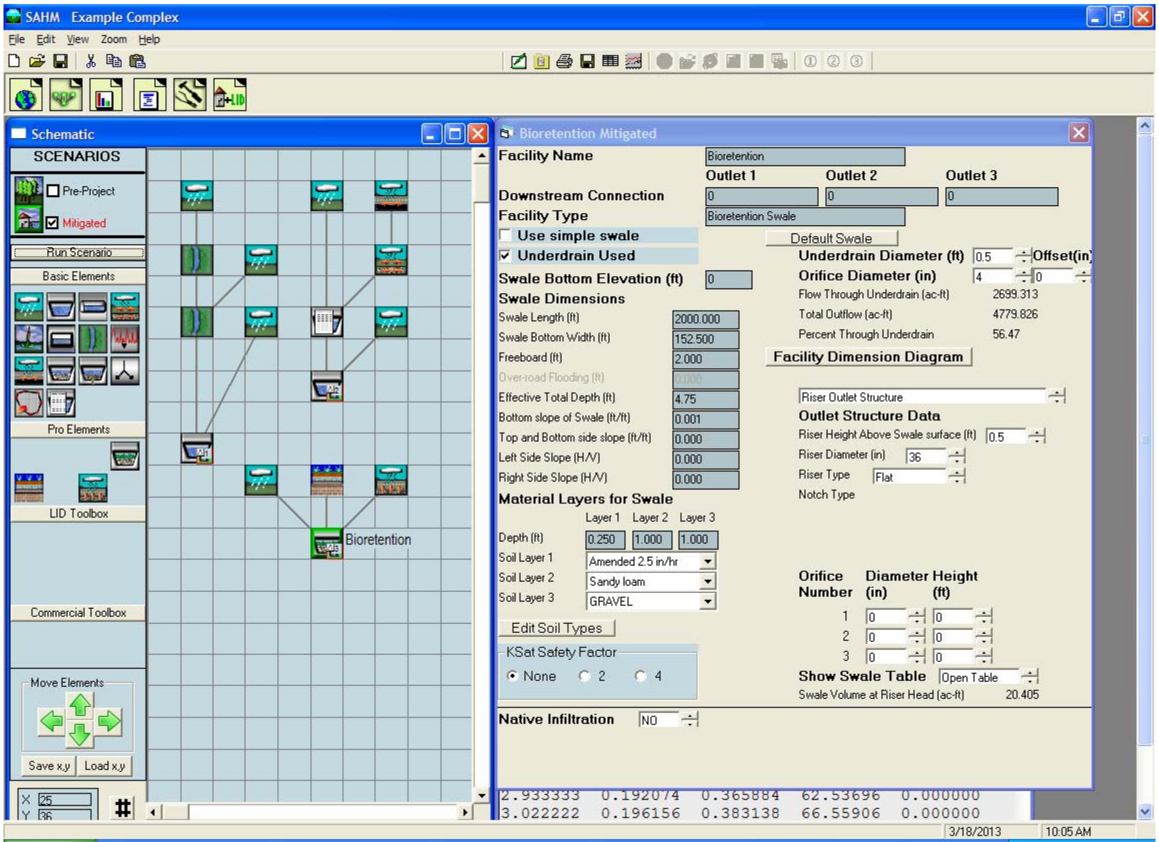


We use Auto Pond to size DMA 2 Pond.

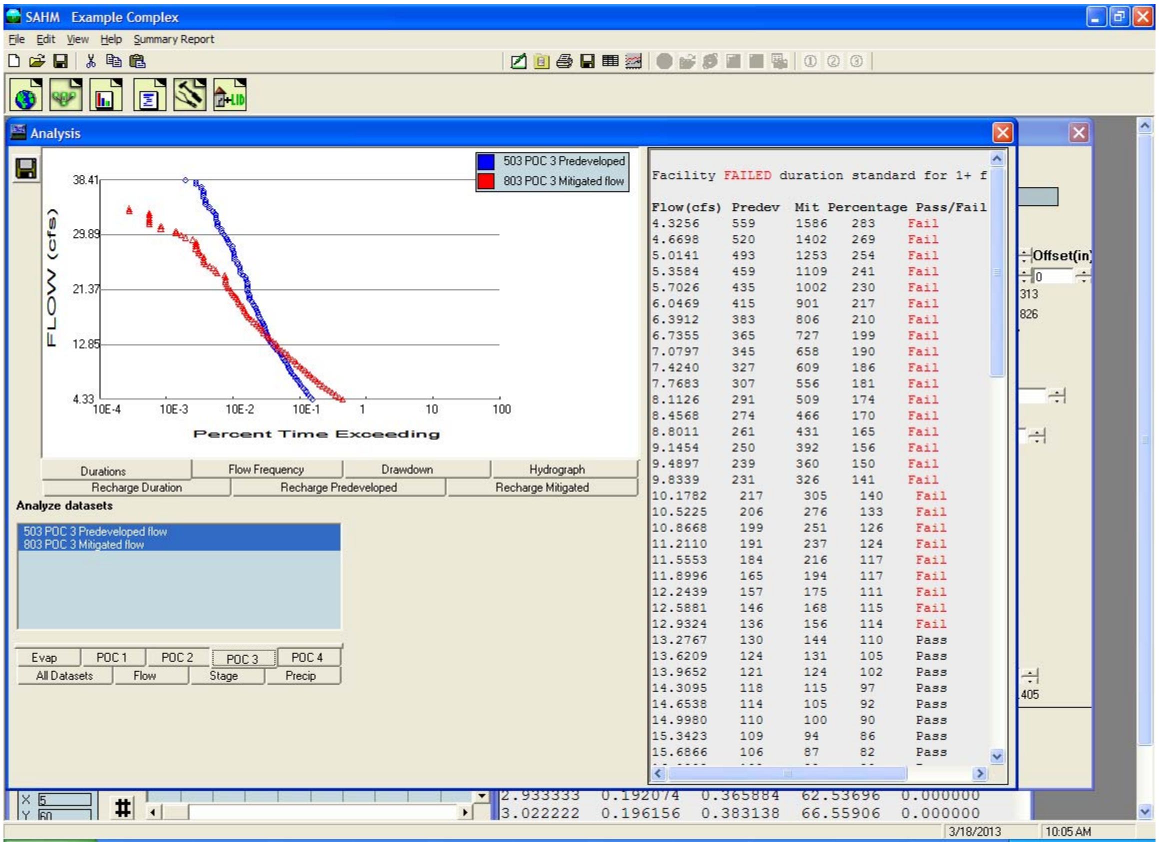
DMA 3 has a combination of land uses including permeable pavement and a 1-acre green roof. Everything drains to the bioretention facility; we will have to size the bioretention manually.



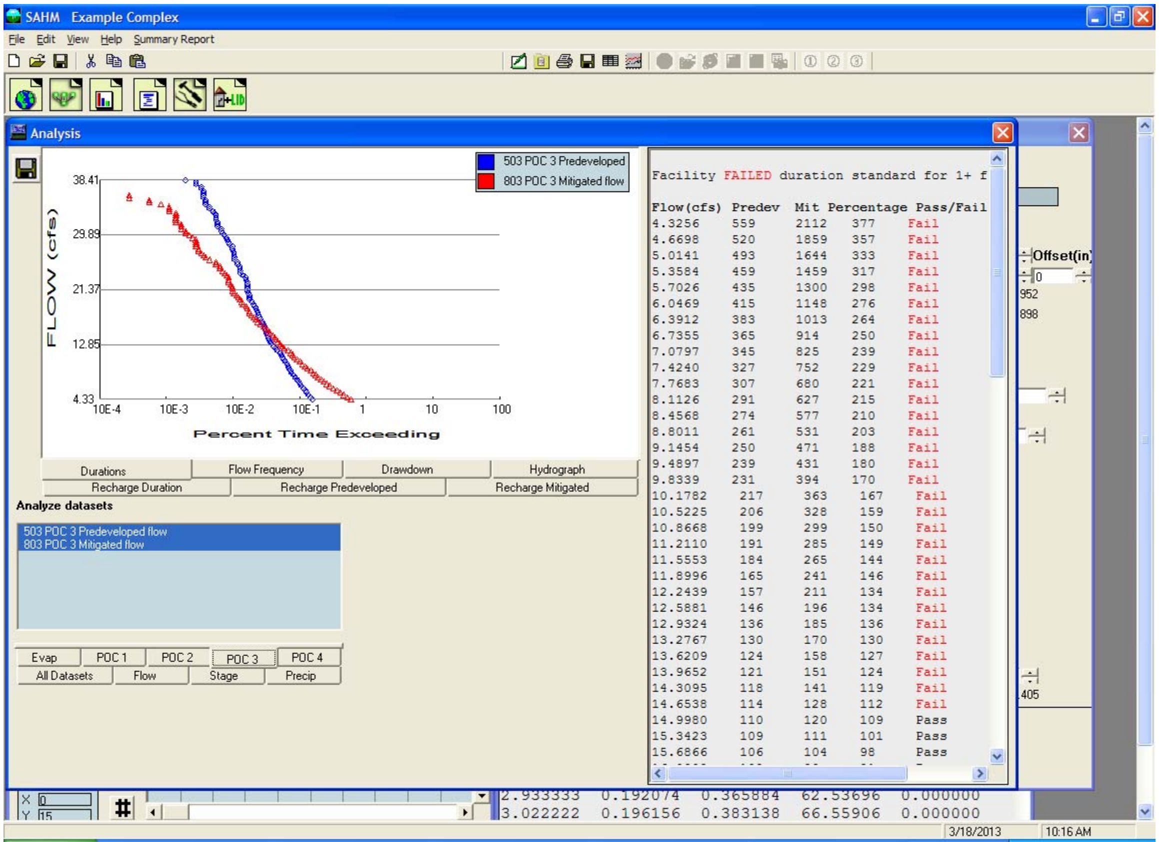
The permeable pavement area is 30 acres. The total area draining to the bioretention is 120 acres, including the permeable pavement area. The general rule-of-thumb is that the bioretention area must be at least 5% of the total area draining to it. We start with a bioretention surface area of 7 acres. In the model rain falls directly on the permeable pavement, green roof, and the bioretention areas, so these acreages are not included in the DMA 3 basin total area.



The bioretention will include an underdrain, but no infiltration to the native soil. The outlet structure will be a riser. Six inches (0.5 ft) of ponding will occur on the surface before there is overflow into the riser. All flow through the material layers exits through the underdrain. The underdrain discharge rate is controlled by the underdrain orifice. We will start with an underdrain orifice of 4 inches.



The flow duration results for POC 3 show that too much water is discharged at the lower end of the flow duration curve. This discharge is controlled by the underdrain orifice. Our assumed underdrain orifice diameter of 4 inches is too large. We will reduce it to 2 inches and try again.



Changing the size of the underdrain orifice did not change the flow duration results. That means that too much water is going through the riser and the bioretention area is too small.

We can double the bioretention area from 7 acres to 14 acres. We remove 7 acres of urban landscaping in DMA 3 to compensate for the increase in the bioretention area size.

This procedure of adjusting the bioretention area dimensions and the underdrain orifice diameter continues until the flow duration criteria are met.